PROCEEDINGS

OF THE

FOURTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM THURSDAY SESSIONS VOLUME II

Acquisition Research:

Creating Synergy for Informed Change

May 16-17, 2007

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**ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL**

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Preface and Acknowledgements

Founded in 2003, the Acquisition Research Program (ARP) has become an institutional, multi-disciplinary entity. In 2006 the ARP made significant and sustaining progress toward realizing its goals to:

1. **Position NPS as a recognized leader in defense acquisition research.**

2. **Establish NPS acquisition research as an integral part of policy-making for Department of Defense officials.**

3. **Create a stream of relevant information concerning the performance of DoD Acquisition policies with viable recommendations for continuous process improvement.**

4. **Prepare the DoD workforce to participate in the continued evolution of the defense acquisition process.**

5. **Collaborate with other universities, think tanks, industry and government in acquisition research.**

Since inception, over 100 reports and papers have been published, thereby making a significant contribution to the body of literature on the defense acquisition process. Through these research products, ARP sponsors are receiving substantial help with and insights into the pressing business issues of the day.

The synergy between faculty research and student classroom instruction has been exceptional with many relevant and current instructional materials emerging from research products, thus enhancing the student educational experience. Faculty are "refreshed" in defense-relevant subject matter, and students are better prepared to enter the acquisition work force. In recognition of these successes, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)) provided $1M in funding for additional projects. This funding expands the ARP by 30% and is a pilot for future increases in research funding.

Researcher opportunities provided by the Chair offer significant benefits to researchers: (1) provision of funding saving researchers "marketing" time; (2) ties with sponsor POCs thus assuring DOD relevant research; (3) assistance with final formatting, editing and publishing thus relieving researchers from the "non-intellectual" aspects of their research. Each of these is a substantial benefit but the growing connectivity between researchers and sponsors is paying large dividends to all concerned. While we at the Naval Postgraduate School like to think of our institution as the world's leader in defense acquisition research, we also recognize that, because of our limited size and resources, we are able to study only a few of acquisition's myriad of complex issues and challenges. We know that genuine progress in acquisition research can be achieved and sustained only to the extent that scholars from a broad range of institutions and disciplines are engaged to participate. Once this "critical mass" of researchers is formed, we may anticipate that acquisition will become a field of its own, with perhaps a variety of acquisition journals, acquisition conferences, and university courses in acquisition management and policy.

Such intellectual capacity, we may hope, will before long prevail against acquisition's perennial and often pernicious problems.

Accordingly, the year 2006 was especially significant for the NPS Acquisition Research Program in taking major strides toward expanding the program's reach in important ways to other institutions. The number of research institutions participating as collaborators grew to 35 with the formation of a Virtual University Consortium. Most noteworthy was, as mentioned above, our securing sponsorship from USD(AT&L) to fund research proposals selected from a nationwide call, or Broad Agency Announcement (BAA) (copy available at www.acquisitionresearch.org). We're truly excited at the prospects of receiving innovative and cutting edge proposals from the top minds around the country. We trust that this new sponsorship will act like good seeds sown in fertile soil, yielding rich fruits of profitable acquisition research for many years to come.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

- Under Secretary of Defense (Acquisition, Technology and Logistics)
- Assistant Secretary of the Navy (Research, Development and Acquisition)
- Program Manager (Infantry Combat Equipment)
- Program Executive Officer (Integrated Warfare Systems)
- Program Executive Officer (Littoral and Mine Warfare)
- Project Manager (Modular Brigade Enhancements)
- Program Executive Officer (Ships)
- Dean of Research, Naval Postgraduate School

We also thank UGS Corporation and the Naval Postgraduate School Foundation and acknowledge their generous contributions in support of this symposium.

James B. Greene, Jr.
Rear Admiral, US Navy (ret)

Keith F. Snider, PhD
Associate Professor

The NPS "A Team"

Rear Admiral James B. Greene, Jr. USN (Ret.) — Acquisition Chair, Naval Postgraduate School. RADM Greene develops, implements and oversees the Acquisition Research Program in the Graduate School of Business and Public Policy. He interfaces with the DoD, industry and government leaders in acquisition, supervises student MBA projects and conducts guest lectures and seminars. Before serving at NPS, RADM Greene was an independent consultant focusing on Defense Industry business development strategy and execution (for both the public and private sectors), minimizing lifecycle costs through technology applications, alternative financing arrangements for capital-asset procurement, and "red-teaming" corporate proposals for major government procurements.

RADM Greene served as the Assistant Deputy Chief of Naval Operations (Logistics) in the Pentagon from 1991-1995. As Assistant Deputy, he provided oversight, direction and budget development for worldwide US Navy logistics operations. He facilitated depot maintenance, supply-chain management, base/station management, environmental programs and logistic advice and support to the Chief of Naval Operations. Some of his focuses during this time were leading Navy-wide efforts to digitize all technical data (and, therefore, reduce cycle time) and to develop and implement strategy for procurement of eleven Sealift ships for the rapid deployment forces. He also served as the Senior Military Assistant to the Under Secretary of Defense (Acquisition) from 1987-1990 where he advised and counseled the Under Secretary in directing the DoD procurement process.

From 1984-1987, RADM Greene was the Project Manager for the Aegis project. This was the DoD's largest acquisition project with an annual budget in excess of $5 Billion/year. The project provided oversight and management of research, development, design, production, fleet introduction and full lifecycle support of the entire fleet of Aegis cruisers, destroyers and weapons systems through more than 2500 industry contracts. From 1980-1984, RADM Greene served as Director, Committee Liaison, Office of Legislative Affairs followed by a tour as the Executive Assistant, to the Assistant Secretary of the Navy (Shipbuilding and Logistics). From 1964-1980, RADM Greene served as a Surface Warfare Officer in various duties, culminating in Command-at-Sea. His assignments included numerous wartime deployments to Vietnam as well as the Indian Ocean and the Persian Gulf.

RADM Greene received a BS in Electrical Engineering from Brown University in 1964; he earned a MS in Electrical Engineering and a MS in Business Administration from the Naval Postgraduate School in 1973.

Keith F. Snider — Associate Professor of Public Administration and Management in the Graduate School of Business & Public Policy at the Naval Postgraduate School in Monterey, California, where he teaches courses related to defense acquisition management. He also serves as Principal Investigator for the NPS Acquisition Research Program and as Academic Associate for resident NPS acquisition curricula.

Professor Snider has a PhD in Public Administration and Public Affairs from Virginia Polytechnic Institute and State University, a Master of Science degree in Operations Research from the Naval Postgraduate School, and a Bachelor of Science degree from the United States Military Academy at West Point. He served as a field artillery officer in the US Army for twenty years, retiring at the rank of Lieutenant Colonel. He is a former member of

the Army Acquisition Corps and a graduate of the Program Manager's Course at the Defense Systems Management College.

Professor Snider's recent publications appear in *American Review of Public Administration*, *Administration and Society*, *Administrative Theory & Praxis*, *Journal of Public Procurement*, *Acquisition Review Quarterly*, and *Project Management Journal.*

Karey L. Shaffer — Program Manager for the Acquisition Research Program at the Graduate School of Business and Public Policy, Naval Postgraduate School. As PM, Shaffer is responsible for operations and publications in conjunction with the Acquisition Chair and the Principal Investigator. She has also catalyzed, organized and managed the Acquisition Research Symposiums hosted by NPS.

Shaffer has also served as an independent Project Manager and Marketing Consultant on various projects. Her experiences as such were focused on creating marketing materials, initiating web development, assembling technical teams, managing project lifecycles, processes and cost-savings strategies.

From 2001-2002, Shaffer contracted to work as the Executive Assistant to the Vice President for Leadership and Development Human Resources for Metris Companies in Minneapolis. In this capacity, she introduced project lifecycle and process improvements to increase efficiency. Likewise, as a Resource Specialist contractor at Watson Wyatt Worldwide in Minneapolis, she developed and implemented template plans to address continuity and functionality in corporate documents; in this same position, she introduced process improvements to increase efficiency in presentation and proposal production in order to reduce the instances of corruption and loss of vital technical information.

Shaffer has also served as the Project Manager for Imagicast, Inc. and as the Operations Manager for the Montana World Trade Center. At Imagicast, she was asked to take over the project management of four failing pilots for Levi Strauss in the San Francisco office. Within four months, the pilots were released; the project lifecycle was shortened; and the production process was refined. In this latter capacity at the MWTC, Shaffer developed operating procedures, policies and processes in compliance with state and federal grant law. Concurrently, she managed $1.25 million in federal appropriations, developed budgeting systems and secured a $400,000 federal technology grant. As the Operations Manager, she also designed MWTC's Conference site, managed various marketing conferences, and taught student practicum programs and seminars.

Shaffer has her BA in Business Administration (focus on International Business, Marketing and Management) from the University of Montana. She is currently earning her MBA from San Francisco State University.

A special thanks to our editor Jeri Larsen for all that she has done to make this publication a success, to David Wood and Carl Matsen for production, to Ian White for graphic support, to Lindsay D'Penha for CD programming, to Jordy Boom for conference website development. We would like acknowledge Arlene Pulido, Jennifer Watson, Bon Troung, Toan Tran and Jason Munoz of the staff at the Graduate School of Business & Public Policy for all the administrative support on the backend to make the Symposium a success. Our program success is directly related to the combined efforts of many.

ACQUISITION RESEARCH:

CREATING SYNERGY FOR INFORMED CHANGE

5th Annual Acquisition Research Symposium

May 14 - 15, 2008

Monterey, California

Announcement and Call for Proposals

The Graduate School of Business & Public Policy at the Naval Postgraduate School announces the **5th Annual Acquisition Research Symposium** to be held **May 14-15, 2008 in Monterey, California.**

This symposium serves as a forum for the presentation of acquisition research and the exchange of ideas among scholars and practitioners of public-sector acquisition. We seek a diverse audience of influential attendees from academe, government, and industry who are well placed to shape and promote future research in acquisition.

The Symposium Program Committee solicits proposals for panels and/or papers from academicians, practitioners, students and others with interests in the study of acquisition. The following list of topics is provided to indicate the range of potential research areas of interest for this symposium: **acquisition and procurement policy, supply chain management, public budgeting and finance, cost management, project management, logistics management, engineering management, outsourcing, performance measurement, and organization studies.**

Proposals must be submitted by **November 9, 2007**. The Program Committee will make notifications of accepted proposals by **December 7, 2007**. Final papers must be submitted by **April 4, 2008** to be included in the Symposium Proceedings.

Proposals for papers should include an abstract along with identification, affiliation, and contact information for the author(s). Proposals for papers plan for a 20 minute presentation. Proposals for panels (plan for 90 minute duration) should include the same information as above as well as a description of the panel subject and format, along with participants' names, qualifications and the specific contributions each participant will make to the panel.

Submit paper and panel proposals to www.researchsymposium.org .

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NPS BAA-07-002

BROAD AGENCY ANNOUNCEMENT

Acquisition Research Program

Naval Postgraduate School

Open until 4:00 pm PDST 1 June 2007

Primary objective is to attract outstanding researchers and scholars to investigate topics of interest to the defense acquisition community. The program solicits innovative proposals for defense acquisition management and policy research to be conducted during fiscal year (FY) 2008 (1 Oct 07 -30 Sep 08).

Defense acquisition management and policy research refers to investigations in all disciplines, fields, and domains that (1) are involved in the acquisition of products and/or services for national defense, or (2) could potentially be brought to bear to improve defense acquisition. It includes but is not limited to economics, finance, financial management, information systems, organization theory, operations management, human resources management, and marketing, as well as the "traditional" acquisition areas such as contracting, program/project management, logistics, and systems engineering management.

This program is targeted in particular to U.S. universities (including U.S. government schools of higher education) or other research institutions outside the Department of Defense.

The Government anticipates making multiple awards up to $100,000 each for a basic research period of twelve months. NPS plans to complete proposal evaluations and notify awardees in early August 2007.

Full Text for NPS BAA-07-002

at

http://www.nps.edu/Research/WorkingWithNPS.html

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Thursday, May 17, 2007

Keynote Speaker

Thursday, May 17, 2007	Keynote Speaker
8:00 a.m. – 9:15 a.m.	**Keynote Speaker** **Mr. Shay D. Assad** – Director, Defense Procurement and Acquisition Policy, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics)

Keynote Speaker: Mr. Shay Assad assumed his position as Director of Defense Procurement and Acquisition Policy (DPAP) on April 3, 2006. As the Director of DPAP, he is responsible for all acquisition and procurement policy matters in the Department of Defense (DoD). He serves as the principal advisor to the Under Secretary of Defense for Acquisition, Technology and Logistics, the Deputy Under Secretary for Acquisition and Technology, and the Defense Acquisition Board on acquisition/procurement strategies for all major weapon systems programs, major automated information systems programs, and services acquisitions. He is responsible for procurement/sourcing functional business process requirements in the Department's Business Enterprise Architecture (BEA) and Enterprise Transition Plan (ETP). Mr. Assad is DoD's advisor for competition, source selection, multiyear contracting, warranties, leasing and all international contracting matters.

Before assuming this position, Mr. Assad was the Assistant Deputy Commandant, Installations and Logistics (Contracts), Headquarters, Marine Corps, Washington, D.C. He had held the position as the Marine Corps' senior civilian contracting official since June 2004.

Upon graduating with distinction from the U.S. Naval Academy in 1972, he served two tours of duty aboard U.S. Navy destroyers and won recognition as Outstanding Junior Officer, Fifth Naval District. He then served as a Naval Procurement Officer at the Naval Sea Systems Command, where he was responsible for the negotiation and administration of the Aegis Weapons Systems engineering and production contracts.

In 1978, Mr. Assad began working for the Raytheon Company. Between 1978 and 1994 he served in several increasingly responsible contract management positions in Raytheon's largest Electronics and Missile divisions gaining extensive experience in defense, commercial and international contracting. He was intimately involved in numerous major programs such as PATRIOT, HAWK, AMRAAM, PAVE PAWS, BMEWS, Standard Missile, Aegis ER, Sparrow and Ballistic Missile Defense. In 1994, he was promoted to Vice President – Director of Contracts for Raytheon, and was subsequently promoted to Senior Vice President, Contracts in 1997. As such, he was responsible for the contract negotiation and administration activities ($20 Billion) in all of Raytheon's businesses – both government and commercial.

In addition to his contracting duties, Mr. Assad was given numerous program and business management special assignments by Raytheon's Executive Office. These assignments spanned participation in all three of Raytheon's major operating businesses – Government, Aviation, and Engineering and Construction.

In 1998 he was promoted to Executive Vice President and served as the Chief Operating Officer and subsequently, as the Chairman and Chief Executive Officer of Raytheon's Engineering and Construction (RE&C) business. RE&C was a $2.7 billion international company with more than 15,000 professional and craft employees, 24 product lines and 11 major offices worldwide.

After his retirement from the Raytheon Company, in 2001, Mr. Assad established a small business primarily providing consulting and retail services.

Panel 11 - Strategic Financing of DoD Resources and Budget Policies

Thursday, May 17 2007	Panel 11 - Strategic Financing of DoD Resources and Budget Policies
9:15 a.m. – 11:00.m.	**Chair:** **Donald Summers**, Lecturer, Naval Postgraduate School **Discussants:** **William Eggers**, Global Research Director, Deloitte Research Public Sector **E. Sanderson (Sandy) Hoe**, Partner at McKenna, Long & Aldridge, LLP **Jim Hearn**, Director for Federal Programs and Budget Process, Senate Budget Committee **Papers:** ***The Folly of Consequence-free Budget Scoring*** **Gerald S. Koenig**, Hannon Armstrong Advisory Services ***The Budget Scoring Alternatives Financing Methods for Defense Requirements*** **LT Leonard Leos**, USN, **LT Paul Rouleau**, USN, and **LT Mark Wadsworth**, USN, Naval Postgraduate School

Chair: Donald E. Summers, LtCol, USMC (Ret.), CMA, CFM is Lecturer in Financial Management, Graduate School of Business & Public Policy, Naval Postgraduate School. He received an MS from the Naval Postgraduate School. Before retiring from the USMC, he was Program Budget Coordinator for the Chief Financial Officer, Headquarters Marine Corps. He has been employed as a senior financial analyst for Household Credit Services and as the executive assistant to the Chairman/CEO (Mr. Bill Agee) of Morrison Knudson Corporation. His interests are financial & managerial accounting, federal budgeting and armed forces comptrollership.

Discussant: William Eggers, Global Research Director, Deloitte Research Public Sector, is a Senior Fellow at the New York-based Manhattan Institute for Policy Research. He examines how technology can be used to reinvent government structures for greater efficiency. In addition he is the Global Director for Deloitte Research-Public Sector, where he is responsible for research and thought leadership for Deloitte's public-sector practice.

He is the author of two new books on transforming government: *Government 2.0: Using Technology to Improve Education, Cut Red Tape, Reduce Gridlock, and Enhance Democracy* (Rowman and Littlefield, 2005) and *Governing by Network: The New Shape of the Public Sector* (Brookings, 2004).

Eggers is a former appointee to the US Office of Management and Budget's Performance Measurement Advisory Commission and the former Project Director for the Texas Performance Review/ *e-Texas* initiative. The two performance reviews Eggers was involved in identified over $2.5 billion worth of

savings and non-tax revenues for the state. Over 60 percent of the recommendations in the reviews were enacted into law. Mr. Eggers also served as a Commissioner for the Texas Incentive and Productivity Commission and a designee on the Texas Council on Competitive Government.

In addition, Eggers was the Chair of the Government Reform Policy Committee for then Governor George W. Bush during his first presidential campaign. In this capacity he coordinated research for the campaign in government management and reform issues.

Mr. Eggers is the former Director of Government Reform at the Reason Public Policy Institute, a Los Angeles-based think tank. A nationally recognized expert on government reform, Eggers is the 1996 winner of the prestigious Roe Award for leadership and innovation in public policy research and the 2002 APEX award for excellence in business journalism. Mr. Eggers is also the co-author of *Revolution at the Roots: Making our Government Smaller, Better, and Closer to Home* (The Free Press). The book was named the winner of the 1996 Sir Anthony Fisher International Memorial Award for the book "making the greatest contribution to the understanding of the free economy during the past two years."

Prior to joining the Reason Foundation, Mr. Eggers assisted reformers in Eastern Europe and the former Soviet Union with the transition from socialist to free-market economies as a policy analyst at The Heritage Foundation in Washington, D.C.

Mr. Eggers has advised dozens of cities, states, and foreign countries and trained hundreds of public officials on restructuring government.

Mr. Eggers graduated magna cum laude from the University of California at San Diego.

Discussant: E. Sanderson (Sandy) Hoe, Partner at McKenna, Long & Aldridge, LLP, work encompassed counseling and litigation on behalf of clients on a broad range of government contracts laws and regulations. His expertise extends from issues in contract formation, including bid protests, the negotiation of subcontracts and the structuring of complex private financing, to the preparation of complex claims, and to resolution of post-award contract disputes through litigation or alternate dispute resolution methods. His clients include major companies in the defense, telecommunications, information technology, financial, and health care industries.

Sandy has counseled clients on government socio-economic programs, the flowdown of requirements to government subcontractors, the application of international agreements such as the Buy American Act and Trade Agreements Act to government contractors and a host of other issues. He has litigated multi-million dollar contract disputes involving government allegations of contractor defective pricing and failure to perform. His litigation experience includes challenges to government refusal fully to reimburse contractors terminated for convenience. He has settled major prime - subcontractor disputes through mediation. He served on the ABA committee that prepared model flow-down terms and conditions for subcontracts under government prime contracts following adoption of the Federal Acquisition Regulation in 1984. He also is expert on efforts by the government to outsource work to the private sector and co-chairs the ABA's Public Contract Law Section, Privatization and Competitive Sourcing Committee.

In the area of finance, and to help clients take advantage of government initiatives to privatize certain of its activities, Sandy successfully has counseled clients in the creation of third-party financed government contracts, including long-term leases, and related ancillary agreements for such items as ships, aircraft, military housing, energy facilities and information technology. Clients in this field have included major contractors, banks, investment bankers and insurance companies.

Sandy is the author of "Law for Engineers" (George Washington University, 1980) and "Flow-Down Clauses in Subcontracts," *Briefing Papers* (Federal Publications, Inc.). He was a professorial lecturer in Engineering Law at George Washington University (1980-1984) and has lectured for Federal Publications, Inc., the National Contract Management Association, the American Bar Association, and

industry groups. He served for six years on the Steering Committee of the Section on Government Contracts and Litigation of the District of Columbia Bar, including three years as co-chair.

For several years, Sandy also practiced telecommunications regulatory law, appearing before numerous state public utility commissions in hearings to open the local exchange markets for new entrants under the Telecommunications Act of 1996.

Discussant: Jim Hearn, Director for Federal Programs and Budget Process, Senate Budget Committee

The Folly of Consequence-free Budget Scoring

Presenter: Gerald S. Koenig is Managing Director of Hannon Armstrong Advisory Services, a firm that advises government and corporate clients on the economics and financing of critical infrastructure needs. He has over twenty years of experience in senior executive and legal positions and served both on the White House staff under President Ronald Reagan and in the Office of Secretary of Defense under Richard Cheney. Mr. Koenig received a BS in engineering from West Point, an MA in International Relations from USC, and a JD in International Business Transactions from the George Mason University School of Law; he is a member of the District of Columbia Bar.

HA Advisory Services advises government and corporate clients on how to use multiyear Federal funding to acquire critical infrastructure needs. HA Advisory Services is an affiliate of Hannon Armstrong Capital, which for over 25 years has provided financing for government infrastructure projects.

Things and actions are what they are, and the
consequences of them will be what they will be;
why, then, should we desire to be deceived?

Bishop Joseph Butler
1692-1752

Overview

Current Congressional Budget Office (CBO) budget scoring rules cheat taxpayers and warfighters by ignoring the high cost of not acquiring cost-effective upgrades to critical combat weapons. Treating paid-over-time procurements as if they are paid-up-front budget outlays necessarily perpetuates waste and inefficiency where we can least afford it: on the modern battlefield. As a result, the current acquisition process for such upgrades involves a simplistic, two-step process. First, determine if paying the entire cost up-front of an upgrade is less expensive than the net present value of paying for the upgrade over time. Once paying up-front is "discovered" to be the cheaper option (as nearly always occurs), the next step is to abandon the upgrade as soon as it fails to compete successfully for scarce procurement budget dollars. An extremely conscientious program official may repeat this process for a number of budget cycles. But in the end, the outcome is predictable. The game is just rigged that way.

The problem is that these policies have real consequences that squander taxpayer dollars while degrading battlefield performance. Many of America's major combat weapons systems have engines that are so old and obsolete that modern upgrades would easily pay for themselves in fuel and maintenance savings <u>while dramatically increasing combat range and battlefield reliability</u>. The private sector is willing to give the DoD such upgrades at no upfront cost in exchange for annual "mortgage-like" payments that are never greater than verified savings in fuel and maintenance. How can we know this? Because the DoD has routinely used such "paid-from-savings" contracts for over a decade to upgrade infrastructure on military bases. Similar contracts are widely used by the DoD to acquire vast amounts of information technology and telecommunication assets.

But when legislation was introduced in Congress to extend paid-from-savings contracts to combat platforms, the CBO "scored" the legislation so high that it effectively killed the legislative effort. The CBO insists that paid-over-time acquisitions should "score" for budget purposes in the same manner as if an outright purchase was made—even if the payments-over-time are limited by law to the verified savings produced by the acquisition. By counting the

payments and ignoring the savings as "speculative," the CBO ensures wasteful outcomes; the more an upgrade saves, the more the CBO will assert it costs.

The CBO claims that accounting for acquisitions in any other manner is inconsistent with the *Budget Act* of 1967. The fact is that that Act and all Federal budget laws are silent on this issue. The CBO's position is really a hunch—no more than one interpretation of general principles. The CBO's counterpart in the Executive Branch, the Office of Management and Budget (OMB), reaches the opposite conclusion.

The CBO views its scoring policy in a consequence-free vacuum and sees its role as a dispassionate arbiter of how to apply general budget principles to specific legislation. Actual outcomes are seen as irrelevant—or, at the very least, as highly speculative and, therefore, properly dismissed.

Supporting this dysfunctional acquisition system is an almost smug attitude among many defense acquisition policy apparatchiks. Unfortunately, military and civilian officials who should be fierce advocates for warfighters on such policy issues are missing in action on this issue. Since the Boeing tanker lease scandal, anyone who challenges the orthodoxy of traditional defense procurement is considered, at best, politically tone-deaf.

Government accounting procedures should serve the mission of the government—not vice-versa. If the National defense mission of the Federal government is important enough to siphon off wealth from citizens in the form of taxes, the first rule should be that every tax dollar must buy the most combat power possible. Budget rules that frustrate this purpose need to be changed.

Why Inefficiency Matters on Combat Platforms

The President's 2006 State of the Union address should resonate in many quarters, including in the President's own Executive Branch. Nowhere is the "addiction to oil" that the President cited more serious than in the Federal government, which enjoys the distinction of being the largest single consumer of energy in the world. Within the Federal government, the Department of Defense leads all agencies in consumption of oil. This is not surprising, considering the vast arsenal of tanks, ships, aircraft and bases that the DoD uses in its critical warfighting operations.

What is surprising, however, is how brave Americans are sent into battle with obsolete oil-consuming systems that would be cheaper to replace with state-of-the-art upgrades. Some of our most famous aircraft and other weapons systems are long overdue for new engines since their forty-year-old engines are underpowered and undependable—and waste billions of taxpayer dollars on fuel.

Breaking any addiction requires that one first admit there is a problem. As taxpayers, we have a problem with Federal accounting rules that are rigged to waste our tax dollars. As for warfighters, their problem is that these same policies send them into battle with second-rate equipment. But all of us have a common problem: Federal accountants clearly could not care less about these outcomes; their attitude is simple: *It's not my department.*

Since the American Revolution, how the government buys military goods and services been a source of constant concern—and with good reason. Failing to get the most for each taxpayer dollars is always bad, but it is hard to imagine a greater abomination than when

American warfighters are sent into battle with second-rate equipment when first-rate equipment could bought at less cost. Historically, war profiteers and corrupt bureaucrats are the usual suspects, but here the culprits are myopic budget officials.

Most Americans would be surprised to learn that some of our best-known weapons are grossly underpowered by forty-year-old engines that cheat warfighters of combat range and power while cheating taxpayers by guzzling gas and requiring ever-increasing amounts of maintenance. Reengining with state-of-the-art engines could give warfighters the best "bang for the buck" while taxpayers would harvest a windfall in savings. The savings are so great and so certain that the private sector has offered the DoD a compelling offer: Let us <u>give</u> you the new engines, and you can pay us back from the savings—but only if and when those savings materialize.

The DoD routinely accepts such offers when the stakes are low, such as upgrading energy systems on military bases. Congress created *Energy Savings Performance Contracts* in the 1990s for exactly this purpose. Since then, billions of taxpayer dollars have been saved using these "paid-from-savings-over-time" contracts. The advantage is not just a matter of making defense contractors guarantee savings. The real advantage is that these contracts break the cycle in which aging engines rarely compete successfully for full, up-front funding in the Federal budget process.

That cycle is, after all, how these assets got to be old and obsolete in the first place. Nevertheless, many OMB and CBO budget officials fail to see this is a problem, despite it being documented in numerous DoD and Air Force studies and reports to Congress. The accountants remain fixed in their belief that if replacing obsolete engines was important enough, the DoD's limited capital budget would be allocated to that purpose. These same accountants are not bothered that the other major part of the defense spending, the "operations and maintenance" budget, is being drained by these gas-guzzling maintenance hogs year-in and year-out—even when offered a paid-from-savings solution that pays for the new engines out of savings from existing operations and maintenance budget levels. *Tough luck, soldier*, is their bottom line.

Of course, buying anything over time is more expensive than paying cash up-front. But as long as there is a National Debt, even capital appropriations from Congress cost the taxpayers interest. Thus, the issue is really how much *more* interest does an Energy Savings Performance contract cost the taxpayers, and what do the taxpayers get for that extra cost? Moreover, the real world choice is not just between buying outright or buying over time. The third—and most often selected—choice is simply to do nothing.

Unfortunately, doing nothing can be the worst choice of all. This is exactly what is occurring in a surprising number of combat fleets, from Abrams tanks to B-52 Bombers. To be clear, a legacy tank, aircraft or ship itself may still have decades of useful life. After all, it's hard to wear out a tank. And until some new enemy advances Panzer-technology, the Abrams tank is unlikely to meet its match on a battlefield anytime soon. The same goes for B-52 and the Joint STARS aircraft fleets—and any number of other legacy fleets.

But technology advances at different rates in different areas. So, while these ships, tanks and aircraft may still be perfectly suited for battle, their engines often are not. Engine technology has advanced so profoundly in the last few decades that state-of-the-art engines can quickly pay for themselves in fuel and maintenance savings—and do this while providing greater power, combat range and battlefield reliability. A recent Air Force study estimated that reengining the B-52 fleet alone would pay for itself in less than half of the remaining life of the

airframe, extend combat range by 30% and save so much fuel that even in peacetime, it would be equivalent to taking over 144,000 cars off the road each year.

None of this is disputed by the DoD, Congress or the White House. So, why are we still sending brave Americans into battle with obsolete equipment that costs taxpayers more than state-of-the-art alternatives? The reason is simple: Federal accountants are blocking combat upgrades that save money and lives because their accounting rules are based on bad logic.

Just as with energy system upgrades on military bases, there are generally three choices with obsolete engines. First, you can buy the upgrade outright, assuming that reengining B-52s, Joint STARS or Abrams tanks can compete for scarce capital appropriations. Second, you can buy the upgrade over time, matching payments with the savings produced by the upgrade, thereby spending no more in any given year than would have otherwise been spent. Third, you can do nothing.

Again, no one disputes these alternatives. In fact, a recent DoD study submitted to Congress even identified the lifecycle costs for each of these three alternatives for replacing the forty-year-old engines on one of America's most successful combat aircraft: Joint STARS:

Option A: Outright Purchase: $ 1.0 Billion

Option B: Purchase Over Time: $ 1.2 Billion

Option C: Do Nothing: $ 1.5 Billion

Any reasonable person would quickly understand that Option A is the best choice. And if for some reason Option A is not possible, Option B is the next best alternative. Clearly, Option C is the worst choice.

But when viewed through the prism of Federal budget policy, the logic gets twisted in this way: Because Option B costs more than Option A, Option B must be eliminated from any further consideration. So the choice is between Option A and Option C. But history shows Option A is not a realistic possibility, since the DoD usually has more urgent priorities than replacing engines that, after all, still work. So Option C is the end result.

Privately, everyone agrees that Option A is not likely to happen. Like a frog in boiling water, Federal decision-makers never really feel the pain of creeping obsolescence in weapons systems. As a result, even the most economically sound upgrades rarely compete successfully for budget dollars against higher priorities. Nor is this necessarily a bad decision. Imagine having to choose between upgrading Humvees with either new armor against roadside bombs or a new engine. New armor will save lives right away, so it should (and does) get priority.

This example is representative of the difficult choices made every day. The point is that even if we assume that DoD and Congress sort out these priorities properly, shouldn't Option B at least remain on the table for consideration? If "paid-from-savings" contracts are a legitimate tool for upgrading the rear echelon, why shouldn't the tool be available on the front line?

Several years ago, a bipartisan group of Senators and Congressmen ranging from Senators Sue Collins to Pat Roberts to Hillary Clinton introduced legislation that would allow the DoD to use Energy Savings Performance Contracts to upgrade combat aircraft, ships and vehicles. This was a bill (S. 2318 / H.R. 3339) that appealed to hawks, environmentalists and

anti-government waste advocates equally. There was no apparent opposition until the CBO and OMB accountants successfully killed the effort.

The CBO asserted that Energy Saving Performance Contracts outlays are real, but their savings are speculative—even though they are, by law, a mathematical identity. The House Energy Committee Chairman, Joe Barton, called the CBO's reasoning "absurd," and Senate Energy Committee Chairman (and former Budget Committee Chairman) Pete Domenici stated: "CBO views these contracts as outlays by the federal government. The truth is that these contracts cost the government nothing."

But because of the CBO, Congress was barely able to muster the votes to reauthorize these contracts for use in upgrading military buildings, gagging down a $2.8 billion "score" from the CBO. Tragically for our warfighters and taxpayers, the CBO's Alice-in-Wonderland accounting estimated an expansion of these contracts for use on combat systems at about $15 billion. This "cost" was too much for anyone to ignore, but not enough for anyone to engage in a political firefight with the CBO. So, the *Energy Act* of 2005 was passed with Energy Savings Performance Contracts for military buildings fully reauthorized, but nothing authorized for battlefield assets.

The great irony is that the CBO's scoring policy makes it painful to save a little taxpayer money and impossible to save a lot.

Contributing to and applauding this perverse outcome is the OMB, the accountants for the Executive Branch, including the DoD. To their credit, the OMB believes that Energy Savings Performance Contracts cost the government nothing. But the OMB went out of its way to disparage using this proven tool to upgrade combat systems. The reason? Only that, "it is inconsistent with Federal fiscal and procurement policies." No kidding…

In a less dangerous world, wasting defense dollars by equipping our warfighters with second-rate equipment that costs more than first-rate alternatives would simply be irrational. But for the foreseeable future, irrational budget policies will continue to have very real and dangerous consequences for the brave Americans we send into battle.

Warfighters deserve more respect than these accountants give them. And the Bush Administration and Congress should get serious about where their priorities are: with the taxpayers and warfighters, or with the accountants.

Background

The original statute creating Energy Savings Performance Contracts (ESPCs) was the *Energy Policy Act of 1992*, Public Law 102-486, enacted October 24, 1992, codified at 42 USC 8287. The CBO scored the ESPC provisions of the *Energy Policy Act of 1992* at zero.

The sunset date of the original statute was amended to become October 1, 2003, by the *Energy Conservation Reauthorization Act of 1998* (Public Law 105-388, enacted November 13, 1998). Again, the CBO scored the ESPC provisions of the *Energy Conservation Reauthorization Act of 1998* at zero.

The CBO reversed this decade-old policy of scoring ESPCs at zero on April 7, 2003 in their Cost Estimate for H.R. 1346, in which the CBO stated:

Currently, federal agencies can enter into an ESPC, a specific type of long-term contract, for the purchase of energy efficiency equipment, such as new windows and lighting. Using such equipment can reduce the energy costs for a facility. When using an ESPC, the savings from reduced energy bills are used to pay for the purchase of the new equipment over several years. The commitment to make such payments is made when the ESPC is entered into. Thus, consistent with governmentwide accounting principles, CBO believes that the budget should reflect that commitment as new obligations at the time that an ESPC is signed. Currently, agencies can use ESPCs to purchase new equipment over a 25-year period without an appropriation for the full amount of the purchase price.

DOE estimates that agencies entered into ESPCs valued over $800 million since 1988. CBO estimates that, because the federal building inventory is aging, those contracts would continue to be used over time at roughly the same rate currently used, or $75 million in 2004 and increasing after that. Thus, we estimate that extending the authorization for ESPCs would increase direct spending by about $64 million in 2004 and $1.1 billion over the 2004-2013 period.

This Cost Estimate was prepared by Lisa Cash Driskill and approved by Peter H. Fontaine, Deputy Assistant Director for Budget Analysis.

The following day, on April 8, 2003, the CBO published their Cost Estimate for H.R. 6, which states:

Energy Savings Performance Contracts (ESPCs). Section 11006 of H.R. 6 would provide permanent authorization to use ESPCs and would expand their use. The expansion would allow agencies to use an ESPC to construct replacement buildings by committing to pay private contractors a portion of the budget savings expected from reduced operations, maintenance, and energy costs at such new buildings. CBO estimates that this provision would cost $75 million in 2004, $879 million over the 2004-2008 period, and $2.8 billion over the next 10 years.

Again, this section of the Cost Estimate for H.R. 6 was prepared by Lisa Cash Driskill and approved by Peter H. Fontaine, Deputy Assistant Director for Budget Analysis.

In sum, the CBO recognized that ESPCs cost the government nothing and scored ESPC authorization and reauthorization at zero in 1992 and 1998, respectively. In 2003, with no meaningful explanation, CBO reversed this policy and scored ESPCs as direct spending.

For its part, the Office of Management and Budget (OMB) rejects the CBO's new ESPC scoring policy and continues to score ESPCs as budget-neutral except for termination liability, which is scored only if and when such termination actually occurs. This OMB policy is set forth in the July 25, 1998, OMB memorandum *Federal Use of Energy Savings Performance Contracting* (Retrieved from http://www.whitehouse.gov/omb /memoranda/m98-13.pdf).

This policy, originally established in the Clinton Administration, was reaffirmed as the policy of the Bush Administration by the Secretary of Energy in letters to the Chairmen of the House and Senate Energy Committees, dated April 8, 2004, in which Secretary Abraham states:

The legislation itself extending ESPC authority is considered budget neutral and does not require additional resources, as the Office of Management and Budget classifies all budget authority and outlays for ESPCs as absorbing discretionary resources. However, ESPCs actually save the government money, because the upfront costs of ESPC efficiency improvements are recovered through the energy savings that result. Moreover, payments to the contractors are contingent upon realizing a guaranteed stream of future cost savings.

Improved energy efficiency and conservation at Federal facilities is an important component of this Administration's commitment to the cost-effective use of public dollars and protection of the environment. The Administration urges Congress to act quickly to the authorization of this important program.

Thus, the consistent position of the Executive Branch through both the Clinton and current Bush Administrations is that ESPCs should be scored at zero. The reasoning for this is compelling since, contrary to CBO's claim that the government's "commitment to make such payments is made when the ESPC is entered into," the government's commitment to make payments under an ESPC only is made when, and to the extent, savings are achieved in each year of the ESPC. This is set forth explicitly in 42 USC 8287 (B), which states:

Aggregate annual payments by an agency to both utilities and energy savings performance contractors, under an energy savings performance contract, may not exceed the amount that the agency would have paid for utilities without an energy savings performance contract (as estimated through the procedures developed pursuant to this section) during contract years.

Thus, contrary to the CBO's assertion that its new ESPC scoring policy is, "consistent with governmentwide accounting principles," no other entity within the federal government has ever accepted the CBO's policy. Just the opposite is true: Not scoring ESPC payments is, and always has been, the governmentwide accounting principle.

Economic Logic Compels ESPCs Scoring at Zero

The fundamental economic basis for not scoring ESPCs is that the opportunity cost of an ESPC (i.e., the government's next best alternative to the ESPC) is to continue to pay (what by law must be) a higher amount for ongoing energy and maintenance costs on the aging infrastructure that the ESPC would upgrade.

The fact that ESPCs must reduce pre-existing government obligations makes ESPCs unique among all financing vehicles available to the government. Scoring ESPC payments without deducting the higher payments the government would otherwise make results in double counting of the true scope of the government obligation.

Put another way, if a government obligation of $100 is replaced with a lesser government obligation of $90, the correct scoring is not $190. While one could argue that the proper score in this case is $90, proponents of ESPCs only ask that the more conservative amount of $100 be recognized as a complete offset to the original $100.

The fact is that using an ESPC cannot increase Federal obligations. At worst, the Federal obligation remains at the same level it would have been if no ESPC were used. It is this worst-case scenario that produces a zero score in any rational budget treatment.

Accounting Logic Compels ESPCs Scoring at Zero

Recognizing that accounting principles sometimes differ from their underlying economic theory, it is worth reviewing ESPC scoring through a purely accounting prism. In the most general sense, Federal accounting divides Federal spending into Operations & Maintenance (O&M) accounts and Capital accounts. In a classic Federal acquisition, an upgrade is purchased by an agency using Capital appropriations provided for that specific purpose by Congress, almost always without any statutory offset requirements. In such a case, the entire amount of that Capital appropriation is properly scored as direct spending. Linking this to its underlying economic justification, it can be said that Congress could spend that appropriation on anything else; thus, its opportunity cost is the full amount of the Capital appropriation.

An ESPC is fundamentally different from such a classic Federal acquisition, precisely because it only draws on the existing stream of the applicable O&M account over the term of the ESPC. The key factor that compels a zero-score accounting treatment is that the ESPC cannot ever draw more from that O&M account than would have been drawn if the ESPC had not been executed. Moreover, the ESPC can never create Federal obligations from any Capital account. Again, linking this to its underlying economic justification, Congress could not spend that portion of the O&M account appropriation on anything else, since it would be spent on fuel and maintenance for the aging asset in the absence of an ESPC; thus, the opportunity cost of an ESPC is spending the same (or greater) amount of O&M appropriation.

In sum, unless there is a contract termination, ESPCs cannot ever lead to an increase in the amount of money that Congress would have otherwise appropriated for any O&M or Capital account.

To be clear, termination of an ESPC can trigger a Federal obligation that would exceed the normal O&M account funding stream. Congress recognized this when it created ESPCs in 1992 and explicitly set forth how such an event should be scored. This provision, codified in 42 USC 8287, states:

1. *A Federal agency may enter into a multiyear contract under this subchapter for a period not to exceed 25 years, without funding of cancellation charges before cancellation, if—*
      ***(i) such** contract was awarded in a competitive manner pursuant to subsection (b)(2) of this section, using procedures and methods established under this subchapter;*

      ***(ii) funds** are available and adequate for payment of the costs of such contract for the first fiscal year;*

      ***(iii) 30** days before the award of any such contract that contains a clause setting forth a cancellation ceiling in excess of $10,000,000, the head of such agency gives written notification of such proposed contract and of the proposed cancellation ceiling for such contract to the appropriate authorizing and appropriating committees of the Congress; and*

(iv) such contract is governed by part 17.1 of the Federal Acquisition Regulation promulgated under section 421 of title 41 or the applicable rules promulgated under this subchapter.

Thus, the proper accounting treatment to provide for possible termination is not a matter for debate or interpretation; it is explicitly established by Congress in Federal law. To the extent that the CBO justifies its radical scoring of ESPCs by citing termination liability exposure, it is contrary to the consensus of Congress expressed in this statute.

Moreover, this law makes tremendous sense and reaches the proper economic result. Accounting for termination costs is clearly appropriate when a termination occurs. But since no one knows the future with certainly, the termination liability amount should be discounted by the likelihood of a termination actually occurring. Historical data shows that less than 1% of all Federal contracts are terminated, either for government convenience or contractor default. Twelve years of experience shows that ESPCs' rate of termination is much better than these government-wide averages.

What Does It Matter?

This CBO scoring policy has a tremendously adverse impact and is against Federal Government interests. Simply put, this CBO scoring policy undermines the original purpose for which Congress intended ESPCs, which is to permit agencies to introduce rational economic upgrades that permanently reduce net costs to the taxpayer.

This CBO scoring policy further undermines the beneficial expansion of ESPCs to the non-installation applications, as was provided for in H.R. 3339 and S. 2318. These upgrades to combat aircraft, tanks and ships are where the majority of benefits to the Federal government would accrue. Because ESPCs in this application also increase the combat range and reliability of military forces, the adverse impact of this CBO policy will result in American forces being sent into battle with less than the best available weapons and support systems *per dollar spent*.

While a healthy debate can always be made on what is the right level of military spending, it is unconscionable that once that level is set, we do not provide our warfighters the most powerful capability that this amount of money can buy.

In a Perfect World

While the immediate solution would be to reverse the CBO's scoring policy on paid-from-savings contracting, there is a more proactive approach that should be considered. The best solution is to adopt more responsible policy along the following lines:

a. The overall acquisition process should result in the compilation and maintenance of a list of acquisitions that make economic and operational sense, using rational and intellectually honest lifecycle cost-benefit analysis.

b. Pay for as many of these acquisitions as possible with the limited capital appropriations available each year. Regardless of how the projects are prioritized (economic priorities will often lose out to political, strategic and tactical priorities), at the end of the process there will be unfunded but worthy acquisitions.

c. For each unfunded but desired acquisition, determine if the potential cost of the acquisition would be offset by a corresponding savings generated by the acquisition.

d. In cases where such an offset is sufficient to cover a multi-year amortization of the acquisition, Federal agencies should be encouraged to use multi-year contracting authority to match the rate of new spending for the upgrade to the rate of new savings generated by the upgrade.

e. Require agencies to consider total savings to the US Treasury, not just savings in their corner of the Federal government. Rational accounting rules for a national government should not encourage tribalism.

Finally, it should be recognized that some upgrades do eventually get funded through the traditional acquisition process. Defenders of the status quo are quick to point to these examples as evidence that the traditional system works. The flaw in this logic is that years of potential savings are lost forever while upgrades wait in line for full funding. The net effect of this folly is that taxpayers and warfighters are cheated for the sake of blind obedience to a bureaucratic system that serves no one but itself.

The Budget Scoring Alternatives Financing Methods for Defense Requirements

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Abstract

This research investigates procurement scoring and the Department of Defense's (DoD) use of alternative financing methods, such as leases and public-private ventures. One of the major impediments to using alternative forms of procurement financing for acquiring defense capabilities is in the budgetary treatment, or "scoring," of these initiatives by the Congressional Budget Office (CBO), the Office of Management and Budget (OMB) and the congressional Budget Committees. The current scoring policy that has been applied to many initiatives essentially negates the financial advantage for using alternative forms of financing. Therefore, this research examines existing policies and their adherence to statutes and the role of the various government organizations and committees in actual recording of obligations and outlays related to financing alternatives used by federal agencies. Preliminary evidence suggests that this emerging area has major importance for future DoD acquisitions in a resource-constrained environment. Included are recommendations for changes in budgetary scoring that encompass the full scope of federal obligations and expenditures while promoting efficient, more rapid and fiscally responsible acquisitions.

Executive Summary

Due to the increasing fiscal pressure caused by the Global War on Terror (GWOT) and the growing burden of entitlement programs, the Department of Defense (DoD) must consider alternative forms of financing, including leases and public-private partnerships (PPPs), to fund necessary programs. This research examines the budgetary treatment, or scoring, of these

financial arrangements by the Office of Management and Budget (OMB), the Congressional Budget Office (CBO) and the House and Senate Budget Committees. Every congressional legislation must be scored in accordance with the federal budget process. Scoring legislation is the process of tracking budget authority, projecting future federal outlays based on the budget authority, and recording the actual obligations and outlays in budget execution. The scoring process can greatly affect a bill's ability to be passed based on the financial considerations made by the CBO, OMB or Congressional Budget Committees.

This research introduces the current applications of leasing and PPPs in the public and private sectors. Additionally, an in-depth analysis of the current scoring process conducted by the CBO, OMB and the Budget Committees will be discussed. These government bodies represent the executive and legislative authorities for financing. This analysis will be applied to three case studies, the budgetary treatment of Energy Savings Performance Contracts (ESPC), and two cases involving the use of PPPs in the Operation and Maintenance of Military Family Housing.

Current scoring and general federal budget policies negate the advantages of using alternative forms of financing such as leasing and PPPs. Therefore, they are not used in the acquisition of major defense assets, even though they have proven to generate substantial benefits for the private sector by providing greater flexibility in financing, encouraging innovation, reducing risks, and saving time and money on projects. This research identifies the scoring policies of both the OMB and CBO and recommends a revised scoring policy that applies financial responsibility as well as fair treatment of the advantages of these initiatives. The end goal is not to develop a solution that will revamp the current budget process, but to provide a policy that will to secure funding for needed defense programs while satisfying the requirements of fiscal accountability.

Introduction

The conventional method of procurement for major government acquisitions is full-cost and up-front funding. Full-cost funding means that appropriations must be sufficient to cover a capital project prior to any obligations being incurred. In other words, the full cost of the program must be accounted for in the first year of obligation. The policy provides transparency in the budget; in other words, all programs are scored in the same manner so that proper cost comparisons can be made between projects. Additionally, full funding secures funds for the total cost of the project, minimizing the need for additional funding in the future.

Full-cost funding forces military departments to analyze each project's cost and benefits throughout its life. It ensures that future congressional action is not required to pay for previous congressional spending decisions. Also, full-cost funding empowers program managers to be responsible for time, schedule, and cost parameters of a project. While full-cost funding certainly has its benefits, the policy can cause major fluctuations in appropriations that might eliminate the ability to fund a justified program. Particularly with large acquisitions, full-cost funding consumes a large portion of a military department's available funding resources, thus reducing the funds available for other programs.

With the growing cost of the Global War on Terror (GWOT), particularly with Operations and Maintenance (O&M) and growing technology costs, the Department of Defense (DoD) is under increasing pressure to secure funding for large capital projects with a smaller percentage of the budget designated for new procurement of combat capability. Therefore, alternative financing arrangements, including but not limited to incremental funding, operating leases, out-

leases, share-in-savings contracts, and public private partnerships (PPPs), have attracted interest as potential alternative financing methods. The potential advantages and disadvantages of these financing methods will be analyzed, along with the scoring methods that determine their cost.

The Office of Management and Budget (OMB) for the Executive Branch, the Congressional Budget Office (CBO) and Congressional Budget Committees for the Legislative Branch have the collective responsibility for determining the benefits and costs for DoD appropriations bills. This power, as dictated in the *Congressional Budget Act of 1974*, empowers these agencies as the official "scorekeepers," who determine the actual cost of programs and their relationship to the overall National Military Strategy. However, operating under the same scoring guidelines, divergent scoring results arise between the OMB, CBO and the Budget Committees based on different interpretations of the scoring principles.

This research focuses on the benefits of alternative financing and the scoring of these benefits from alternative financing agreements. With increasing fiscal pressure, these methods are necessary to provide funding for needed acquisitions. In the GWOT and the more hostile world in which we live, the Warfighter cannot wait until the next budget cycle for the equipment needed to complete the assigned mission. A revised scoring policy is recommended to permit the DoD to fund additional procurement projects within the same budget constrains, using fiscally sound, generally accepted accounting principles.

Background into Scoring

The term "scoring" describes the process in which the CBO and OMB estimate the budget authority required by proposed legislation. Budget authority is the authority provided by law to incur financial obligations that will result in monetary outlays (OMB, 2006, June). Scorekeeping determines in a dollar amount the budget effects of legislation and forecasts future outlays needed to fund a program. The "scorekeepers" consist of the Congressional Budget Committees, the CBO, and the OMB. The scoring process and principles used by these entities greatly impact the scored "cost" of a program and, consequently, the ability of the legislation to be passed by Congress. The current scoring guidelines greatly limit the advantages of alternative financing arrangements that attempt to draw on private-sector expertise and funding. This section analyzes the scoring rules that apply to lease, lease-purchase, and capital acquisition arrangements and addresses the disadvantages of the current guidelines. It also provides a background into Energy Savings Performance Contracting (ESPC).

The scoring guidelines contained in OMB *Circular A-11* embody two fundamental principles of federal budgeting:

Federal commitments should be recognized up-front in the budget; at the time those commitments are made.

Budget should be comprehensive, capturing all financial activities of the federal budget (President's Commission on Budget Concepts, 1967, October).

These principles form a policy known as full-funding that requires agencies to request all funding for a project up-front. Prior to 1991, the budget authority and outlays for most leases were recognized annually over the lease term in the form of annual lease payments. This policy allowed agencies to acquire an asset without Congress' consent for the full funding of the asset.

In 1991, new guidelines issued by the OMB scored capital leases and lease-purchases as up-front and requiring full funding. The policy is designed to force decision-makers to determine the entire cost of a project prior to approving the legislation. The up-front funding allows for greater Congressional control over appropriations and also allows Congress to evaluate multiple pieces of legislation on a cost basis. This "transparency" provides Congress with a "standard" with which to monitor the spending of both individual agencies and the entire federal government on an annual basis.

Full funding also better aligns Congressional budget estimates with the *Anti-deficiency Act* (31 USC 1341), which prohibits the government from entering into obligations for the payment of money before an appropriation is made, unless authorized by law. Full funding is a policy rather than a law, which means that the interpretation of the policy can impact the budgetary treatment of a program. Whether an asset is acquired via direct purchase, lease, or through a combination of the two, scoring rules are currently biased towards full funding. These financial arrangements, as well an analysis of the impact of the current scoring rules, will be addressed below.

Federal Budget Principles: Purchases, Leases, and Alternative Financing

Direct Purchases

A simple example of budget scoring is an outright purchase: the government's budget commitment is the purchase price of the asset. Budget authority is assessed equal to the purchase price of the asset at the time when authority is received to acquire the asset. Outlays are then recorded when actual cash payments are made to the seller (CBO, 2003). Outright purchases can be financed through borrowing at a low interest rate from the US Treasury (e.g., Treasury Bills sold publicly), whereas leases require a higher interest rate due to private-sector financing. The scoring policy does not account for several inherent costs of directly purchasing an asset. Full-funding an asset requires the government to assign a larger proportion of the available budget authority to the asset, leaving less budget authority available for other assets in any given fiscal year. Under this policy, a larger opportunity cost exists as decision-makers must often decide between two mutually exclusive programs rather than funding both. Military Departments must often delay or cancel large capital investments that will offer better performance and lower long-term costs to realize short-term savings. Benefits generated by these large projects are realized over several years, whereas the costs must be realized up-front. Outright purchasing may force elected officials to choose between two or more justifiable programs, when both programs could be funded through other means.

Leasing

To distribute the acquisition cost of an asset over its years of use, the government has the ability to lease the asset, or in some cases, to enter into a partnership with private companies to acquire the asset. A simple lease arrangement involves an owner (lessor) renting the use of an asset to another party (lessee). For example, the rental of an automobile from Avis implies no ownership. However, leases can be structured in an almost limitless number of complex arrangements in which all terms are negotiable, and third-party financing may be involved.

To limit the discussion, leases within government are placed into four broad categories: operating leases, capital leases, and lease purchases with or without substantial private risk. The distinction between the different lease types determines how the CBO, OMB and the Budget Committees score budget authority for legislation. Each lease category is discussed below.

To be considered an "operating" lease, a lease must satisfy the following stringent criteria:

Ownership of the asset remains with the lessor during the term of the lease and is not transferred to the Government at or shortly after the end of the lease period.

The lease does not contain a bargain-price purchase option.

The lease term does not exceed 75% of the estimated economic lifetime of the asset.

The present value of the minimum lease payments over the life of the lease does not exceed 90% of the fair market value of the asset at the inception of the lease.

The asset is a general-purpose asset rather than a special-purpose asset for the Government and is not built to unique specification for the Government as lessee.

There is a private-sector market for the asset.

Risks of ownership of the asset should remain with the lessor (OMB, 2006, June, part 8-appendices).

Any lease not satisfying these stringent criteria will be viewed as a "capital" lease. Requirements 5 and 6 (the need for a private-sector market for the asset and the requirement for the asset to be general purpose) essentially eliminate operating leasing for military equipment procurement.

In both operating and capital leases, ownership remains with the lessor and is not transferred to the government at the conclusion of the lease period. In contrast, lease-purchase arrangements allow ownership of the asset to be transferred (GAO, 1997). Determination of risk is another crucial determination in the budget-scoring process. In OMB *Circular A-11*, risk is defined in relation to the government-specific characteristics of the project. The more governmental the project, the greater amount of risk is assigned to the government. Legislation and lease-purchases use the following criteria to determine the amount of risk borne by the government.

There should be no provision of Government financing and no explicit Government guarantee of third-party financing.

Risks of ownership of the asset should remain with the lessor unless the Government was at fault for such losses.

The asset should be a general-purpose asset rather than for a special purpose of the Government and should not be built to unique specification for the Government as lessee.

There should be a private-sector market for the asset.

The project should not be constructed on Government land.

The ambiguity of these guidelines demonstrates that they are more "policies" rather than scoring "rules." The interpretation of these guidelines has been the source of frustration for many private-public partnership initiatives.

The budgetary treatment of the four categories of lease arrangements is summarized in Table 1 below.

Transaction	Budget Authority	Outlays
Lease-purchase Without Substantial Private Risk	Amount equal to asset cost recorded up-front; amount equal to imputed interest costs recorded on an annual basis over the lease period	Amount equal to asset cost scored over the construction period in proportion to the distribution of the contractor's costs; amount equal to imputed interest costs recorded on an annual basis over the lease term
Lease-purchase with Substantial Private Risk	Amount equal to asset cost recorded up-front; amount equal to imputed interest costs recorded on an annual basis over the lease term	Scored over lease term in an amount equal to the annual lease payments
Capital Lease	Amount equal to asset cost recorded up-front; amount equal to imputed interest costs recorded on an annual basis over the lease term	Scored over lease term in an amount equal to the annual lease payments
Operating Lease	Amount equal to total payments under the full term of the lease or amount sufficient to cover first-year lease payments plus cancellation costs recorded up-front	Scored over lease term in an amount equal to the annual lease payments
(CBO, 2003, p. 9)		

Table 1. The Budgetary Treatment of Leases and Private/Public Ventures

For lease-purchases and capital leases, budget authority will be scored against legislation in the year in which the budget authority is first made available. The recorded amount is the estimated net present value of the Government's total estimated legal obligations over the life of the lease term. From a budget perspective, purchases, lease-purchases, and capital leases all attempt to acquire an asset over its total life and are scored similarly. The only major difference involves the treatment of outlays in lease purchases with substantial private risk.

Scoring Policy of Operating leases

Operating leases are different from capital leases or lease purchases because the lessee has no intention to purchase the asset. The budget authority for operating leases will be scored in the first year budget authority is made available in the amount sufficient to cover the Government's legal obligations (OMB, 2006, June). Budget authority for operating leases is scored for the full cost of future lease payments in the first year of a lease; or, if a cancellation clause exists, budget authority for the first year is scored equal to the first year's payment plus cancellation fees, with following years to be scored incrementally.

Advantages of Leases

Leasing provides a number of important advantages in addition to reducing the budget authority assigned to a project. Leasing generally offers a higher degree of flexibility in operating assets, allowing modification of assets to meet changing needs. A compliment of services typically is included with a lease, allowing an organization to draw on the expertise and resources of the lessor. Leasing also conserves capital, which would be required in either a down payment or outright purchase. In the private sector, lease payments can be considered an operating expense and, thus, offer an important tax advantage. As a non-tax paying entity, the government does not have this advantage. However, leasing affords a government agency the ability to spread the acquisition costs over multiple budgetary periods, which will more likely correspond with the useful life of the equipment. Significant up-front costs of direct purchasing may pressure an agency to settle for lower-priced equipment that fails to meet the requirements.

Alternative Financing Agreements: Public-private Partnerships

In August 2003, the Government Accountability Office (GAO) published *Alternative Approaches to Finance Federal Capital*, which examined the increased usage of alternative financing by Federal agencies. The GAO identified ten alternative financing approaches used by Federal agencies to fund projects:

1. Incremental funding,

2. Operating leases,

3. Retained fees,

4. Real property swaps,

5. Sale-leasebacks,

6. Lease-leasebacks,

7. Public-private partnerships,

8. Out-leases,

9. Share-in-savings contracts, and

10. Debt issuance.

The GAO report further recognized that these arrangements would be beneficial to agencies in that they would be able to acquire capital assets without first having to secure sufficient appropriations to cover the full cost of the asset (GAO, 2003, August). Of these financing approaches, public-private partnerships (PPPs) have the greatest potential for DoD procurement of military equipment.

The scoring of public-private partnerships has been a very controversial and important budget issue to those seeking to utilize private-sector resources in government projects. Because no two public-private partnerships (PPPs) are arranged exactly the same, each PPP must be carefully examined prior to any scoring determination. Several of these financing agreements will be examined in the included Case Studies. The major debate revolves around the determination of financial obligation and risk incurred under each of these agreements. Because of the complexity and individuality of many of these arrangements, there is usually no precedent to guide the scoring of these arrangements.

PPPs can be used by the government to affordably take advantage of an underutilized asset, benefiting from private-sector expertise, or leverage private-sector financing in the short-term to acquire a public asset. Leasing may only be small part of the PPP. In some cases, the government may benefit from the revenue a leased asset generates rather than benefit from the use of an asset—serving as the lessor rather than the lessee (CBO, 2003, p. 26). Unfortunately, the Budget Committees, OMB and CBO are typically conservative in their scoring of these arrangements and typically do not discount the inherent benefits of these contracts from the overall budget authority assigned to the contract. The result is up-front budget authority scoring for the project, which may exclude the legislation from being passed. In Case Study Number One, various alternative financing strategies involving governmental housing and buildings will be examined for potential applications to finance military capital acquisitions. In another Case Study, share-in-savings contracts will be examined utilizing the Energy Savings Performance Contracts case. Together, these case studies will demonstrate how current scoring guidelines are used to score alternative financing arrangements based solely on the financial obligation without sufficient regard to the program's benefits.

Barriers to Alternative Financing

A 2003 report written by the Congressional Budget Office addressed the government's concern involving the use of long-term leasing agreements; in particular, their ability to:

1. Reduce the budget's ability to fully depict the Federal Government's financial commitments.

2. Undermine fiscal policy by circumventing controls such as limits on deficits and caps on Federal Spending.

3. Allow an agency to avoid facing the full costs of purchasing an asset at the time it decides to buy it, thus making acquisitions that are not cost-effective more likely.

4. Raise the costs of some investments because a lease purchase is, over the life of an asset, inherently more costly to the government than a direct purchase (CBO, 2003, p. ix summary).

Due to these concerns, there is a large incentive to capitalize the majority of lease agreements, which scores the lease similar to a direct purchase. Since the lease involves payments over time, there is an inherent interest cost disadvantage when delaying the payment of an asset. The scorekeepers use the prime rate or an average of the interest rate of marketable Treasury securities as their standard discount rate. Since private leasing firms require a return that exceeds the prime rate, leasing arrangements incur an additional cost: the difference between the prime rate and the negotiated rate. The scoring rules also assume that parity exists between public and private firms when operating, managing, or maintaining an asset. The additional services and expertise of the private-sector firm are not incorporated into the current scoring guidelines.

Scoring Case Studies

Practical Usage of Alternative Financing

Introduction

As previously mentioned, the GAO identified 10 capital financing approaches in use by government agencies as alternatives to the conventional full-funding approach (GAO, 2003,

August). Five of these 10 approaches were selected for examination on the basis of their potential application towards funding large DoD procurements of capital equipment. These financing strategies include: Incremental funding, Operating leases, Public-private partnerships, Share-in-savings contracts, and Debt issuance. The combined effects of these are reducing the up-front budgetary impact of capital projects, making use of all existing public resources, and incorporating private-sector efficiencies within government projects, which has been a stated goal of every administration since Thomas Jefferson's.

In 1996, Congress passed legislation in the *National Defense Authorization Act;* this bill created the Military Housing Privatization Initiative (MHPI) to address the costly challenge of maintaining adequate housing for service members. Of the 300,000 military housing units in existence, an estimated 200,000 units were in need of repair at an approximate cost of $16 billion, which would restore the units to acceptable conditions (DoD, 1999). The Department of Veterans Affairs (VA) also possesses legislative authority to utilize alternative financing techniques. To alleviate the large up-front costs of their projects, these agencies selected various PPPs as alternatives to conventional funding. Several MHPI and VA projects are presented below to discuss the scoring determination and potential broader application to capital procurement for the DoD.

Public Private Partnerships (PPPs)

In a 2003 study by the GAO, PPPs were identified as the most prevalent alternative financing method, with over 54 different agreements in existence within US agencies (GAO, 2003, August). PPPs are a particularly popular alternative-financing technique for the DoD due to their great flexibility and ability to apply private-sector capital and expertise to public needs and resources. In this symbiotic relationship, each party benefits from its participation in the partnership. The government is unable to be the most efficient provider of all necessary services and equipment items for the public sector. OMB *Circular A-76* acknowledges this reality and provides guidelines with which to outsource public requirements to the private sector and promote efficiency (OMB, 2003, May). In some cases, adaptable technologies or industrial capacity already exist in the private sector that could address the requirements of the military. A PPP can be formed to exploit these opportunities in a manner conventional full-funding procurement cannot.

Despite the efficiencies of PPPs, the scoring of PPP legislation has become increasingly conservative—limiting the flexibility originally granted by statuary authority to several Federal agencies. The CBO and OMB believe that Federal agencies are using special purpose public-private ventures as a way to access private capital without triggering lease-purchase guidelines and to avoid recording obligations up-front in their budgets. This section will discuss these concerns and other scoring issues using several examples from the DoD's privatization of military housing and the VA's enhanced-use lease authority.

The majority of PPPs involve the Federal Government's real property or other underutilized assets that can be developed, revitalized, or managed by the private sector. The key element of a PPP is that the government possesses some non-monetary asset that has value to the private sector. In a typical fully funded contract, the government must set aside funds sufficient to cover all obligations in the first year of the project. In PPP agreements, the government is able to barter an asset or use existing conditions in lieu of full payment to reduce their obligations. These assets can include loan guarantees, longer lease terms, debt issuance, guaranteed minimum rates of occupancy, or even the transfer of the asset at the completion of

the lease term. Figure 1 depicts the wide degree of versatility of PPP contracts in managing responsibility throughout the life of an asset.

Figure 1. Degree of Government Responsibility in PPP Contracts
(Dovey & Eggers, 2007, p. 5)

Below is a listing of the most common PPP relationships in existence.

Design-Build (DB): Under this model, the government contracts with a private partner to design and build a facility in accordance with the requirements set by the government. After completing the facility, the government assumes responsibility for operating and maintaining the facility. This method of procurement is also referred to as Build-Transfer (BT).

Design-Build-Maintain (DBM): This model is similar to Design-Build except that the private sector also maintains the facility. The public sector retains responsibility for operations.

Design-Build-Operate (DBO): Under this model, the private sector designs and builds a facility. Once the facility is completed, the title for the new facility is transferred to the public sector, while the private sector operates the facility for a specified period. This procurement model is also referred to as Build-Transfer-Operate (BTO).

Design-Build-Operate-Maintain (DBOM): This model combines the responsibilities of design-build procurements with the operations and maintenance of a facility for a specified period by a private-sector partner. At the end of that period, the operation of the facility is transferred back to the public sector. This method of procurement is also referred to as Build-Operate-Transfer (BOT).

Build-Own-Operate-Transfer (BOOT): The government grants a franchise to a private partner to finance, design, build and operate a facility for a specific period of time. Ownership of the facility is transferred back to the public sector at the end of that period.

Build-Own-Operate (BOO): The government grants the right to finance, design, build, operate and maintain a project to a private entity, which retains ownership of the project. The private entity is not required to transfer the facility back to the government.

Design-Build-Finance-Operate/Maintain (DBFO, DBFM or DBFO/M): Under this model, the private sector designs, builds, finances, operates and/or maintains a new facility under a long-term lease. At the end of the lease term, the facility is transferred to the public sector. In some countries, DBFO/M covers both BOO and BOOT.

PPPs can also be used for existing services and facilities in addition to new ones. Some of these models are described below.

Service Contract: The government contracts with a private entity to provide services the government previously performed.

Management Contract: A management contract differs from a service contract in that the private entity is responsible for all aspects of operations and maintenance of the facility under contract.

Lease: The government grants a private entity a leasehold interest in an asset. The private partner operates and maintains the asset in accordance with the terms of the lease.

Concession: The government grants a private entity exclusive rights to provide, operate and maintain an asset over a long period of time in accordance with performance requirements set forth by the government. The public sector retains ownership of the original asset, while the private operator retains ownership over any improvements made during the concession period.

Divestiture: The government transfers an asset, either in part or in full, to the private sector. Generally, the government will include certain conditions with the sale of the asset to ensure that improvements are made and citizens continue to be served (Dovey & Eggers, 2007, p. 5).

PPP Examples: Government Privatization Initiative

The statuary authority originally granted in 1996, and later made permanent in 2005, allows the government to enter into public-private partnerships without individual project approval from Congress (10 USC 2871-2885). The relative complexity of PPP contracts frequently generates disagreements amongst the CBO, OMB, and agency representatives concerning the interpretation of the scoring guidelines. The goal of the CBO and OMB is to provide to decision-makers an accurate account of the amount of legal obligations of the federal government. PPPs represent a valuable method of accessing private capital and expertise independent of the scoring determination made by the CBO/OMB. The following DoD and VA case studies analyze the value of the PPPs and the scoring issues in the cases.

Public-private Partnership Case Study 1: Ft. Hood Family Housing, LLP

Description of Project

In 2001, Fort Hood Family Housing was selected as one of the first PPPs by the Army when it contracted Actus Lend Lease to manage all aspects of the development, financing, construction, and property management for the Fort Hood Family Housing project (Fort Hood Family Housing, 2007). The partnership detailed a 50-year lease to maintain the 5,912 units located at Fort Hood, Texas (CBO, 2003, p. 28).

Financial Details

At the conclusion of the initial 50-year lease, the Army has the option to renew for another 25-year lease term. If the Army does not renew, all assets remain government property.

The housing project has an estimated cost of $260 million. The burden of that cost will be divided: $186 million will come in the form of a loan entered into by the partnership; Bank One will provide $20 million in private equity; and the Army will invest $52 million in equity.

Actus will also provide $6 million in equity at the end of the fifth year for additional development. The contract also provides Actus with a preferred return on equity of 10-12%, and a portion of partnership earnings up to a predetermined ceiling. Actus will also receive payment equal to a fixed percentage of the project's gross revenue for its management services.

Scoring Impact and Issues

The Army was able to obtain in excess of $273 million in financing for an up-front cost of $52 million (CBO, 2003, p. 42). Only the Army's direct investment of $52 million was scored by the OMB as an immediate obligation. The transfer of land and pre-existing housing units to Actus had no budget impact based on the absence of any cash transaction between the two entities. A summary of budgetary treatment of asset sales and barters by the CBO and OMB is included in the table below. The rental of the housing units to service members was viewed as individual transactions between private parties. This distributed the budget impact for the housing expenditures to an annual expense vice an up-front cost. Additionally, the $186 million obtained via loan is viewed by the Army as debt of a private entity and not the government. According to the contract details, the Army does not have a legal obligation to cover the costs of the partnership's financing. However, the housing units are located on government land, and the management terms of the contract effectively place the housing under government control.

The actual budgetary impact and actual cost of this PPP has particular significance as the Fort Hood Family Housing, LP, was one of the first PPPs initiated by the DoD. The scoring debate has two clearly polarized sides. From the scorekeepers' perspective, the government's total obligations remain hidden in the financial framework of the partnership, blinding Congress of the needed information to calculate future budget impact. Also, an important underlying issue remains: is this type of partnership actually cost-effective? The deal stipulates a mandated 10-12% return on equity plus a management fee based on the partnership revenues. Could the government provide this service at similar cost and service levels? Another critical issue for the CBO/OMB is the long-term (50 years) lease agreement that represents a long-term commitment to the Fort Hood, Texas base. The long-term lease limits the year-to-year budget control of Congress and obligates the Federal government to unspecified future obligations.

From the service and partnership perspective, the PPP allows the DoD to immediately resolve the issue of substandard and insufficient military housing that threaten the quality of life and retention of the military. The costs of the project are distributed throughout the life of the project. The venture utilizes the housing allowances of the individual service members to finance the agreement over the lease term. Actus Lend Lease, with over 30,000 managed units, is able to offer considerable private expertise that helps achieve a more efficiently run housing project and higher customer-satisfaction levels (Fort Hood Family Housing, 2007). The agreement also alleviates the DoD of housing funding that can now support other missions such as Iraqi reconstruction and development.

PPPs also provide stronger incentives to complete the project on-time and under budget. In 2003, the United Kingdom's National Audit Office reported that 73% of non-Private Finance Initiative (PFI) projects were over budget, and 70% were delayed—versus only 22% of PFI contracts delivered over budget, and 24% delivered late (Dovey & Eggers, 2007, p. 7). The

UK's previous experience in public-private partnerships has demonstrated that non-financial cost factors such as quality, service, timeliness, and expertise can often justify the involvement of the private sector in providing public financing.

This case study highlights the scoring impact of these alternative financial arrangements. For the Fort Hood Family Housing Project, should the up-front obligation for the government be scored at $52 million or $273 million? The CBO asserts that although only a small portion of the total investment has been fronted by the DoD, the DoD has overall controlling interest in the project. The venture is structured to fulfill the service needs; the Army shares in the earnings of the venture above a threshold, and also controls the housing units at the end of the lease. Additionally, military tenants have preferential status for obtaining occupancy, and the venture must maintain affordable rents for service members (CBO, 2003, p. 29). The argument is made that Fort Hood Family Housing Project is a purely government-driven project.

The issue is not whether or not the contract is structured for the service's interests—of course it is. The issue is whether this type of alternative financing is beneficial to both the service and, more importantly, the government as a whole. In this case, the Army should have the flexibility to improve existing military housing with a lower up-front cost of $52 million. Congress and Army leaders must realize, however, that the total obligation to the government will exceed the $273 million total investment upon conclusion of the project. A balance between Congress' desire to control the purse versus the services' need to supply critical services to their members must be reached. The budgetary impact of CBO/OMB scoring will continue to be analyzed in the following case studies.

Public-private Partnership Case Study 2: Chicago West Side Regional Headquarters (CWSRH)

The Department of Veteran's Affairs (VA) was granted authority to enter into enhanced-use lease contracts in 1991 (38 USC 8161-8169). The legislation allows the VA to lease government land to private entities for up to 75 years for the purpose of developing the land for VA or private needs. Payments resulting from the lease can be used by the VA without further Congressional oversight (CBO, 2003, p. 31). The VA then has the option of leasing back the privately developed facilities for their uses. The VA can enter into these agreements without Congressional approval and only must notify Congress within 60 days of the enhanced-use lease agreement. Enhanced-use leases are particularly attractive to the VA due to their vast holdings of underdeveloped land and facilities.

Description of Project

The Chicago West Side Regional Headquarters (CWSRH) project's enhanced-use lease is an example of the flexibility of PPPs, but the project also presents difficult scoring issues to the CBO/OMB. In 2002, the VA entered into a series of agreements used to fund a new $60 million Chicago headquarters building and parking facility (CBO, 2003, p.33).

Financial Details

The project involved numerous interdependent agreements. West Side Enhanced-use Lease Trust was created, with the VA named as sole beneficiary. A four-acre plot adjacent to the VA Medical Center in downtown Chicago was included in the trust, using a 35-year enhanced use lease agreement. MedPark, a private contractor, would be responsible for the construction, outfitting, and management of the office and parking facilities. The Illinois

Department Finance Authority would issue $9 million in taxable revenue bonds to help fund the project. The proceeds from the bond issuance would be loaned to the Trust to pay for the design and construction of the facility. Under the lease terms for the building, the VA is obligated to a two-year lease for a minimum of 95% of the office and parking facilities. The leases are automatically renewing unless the VA renders written notice prior to the end of the lease term. Additionally, if the VA occupies any portion of the building, it must cover at a minimum the amortization and interest of the trust's loans plus all the trustee's expenses (CBO, 2003, p. 34).

Scoring Impact and Issues

In October 2001, the OMB and VA settled how obligations and outlays would be treated for lease-back agreements (CBO, 2003, p. 44). A leaseback agreement is a lease in which the government is the lessor vice the lessee. The agreement stipulated that VA leasebacks of terms up to two years in length would be treated as operating leases, as long as the VA had no right of first refusal on future lease terms. The property lease was drafted to be a non-cash barter transaction without budget impact. The revenues received by the VA from the trust would offset the VA's initial investment and be under the agency's discretion. The initial lease of the building was designed to be an operating lease, and the borrowing of the Trust to be private borrowing. The VA does not have right of first refusal for future leases as mandated by their 2001 agreement with the OMB. The CBO is concerned with the VA's obligation to cover the cost of capital for the Trust even if the agency reduces its usage of the facility.

The CBO points out that the CWSRH enhanced-use lease agreement represents a significant long-term obligation by the VA and is not actually limited to the initial two-year lease term. As such, the budget impact of the project far exceeds the VA's estimation. Congressional scoring is only rendered on new legislation; since the project was passed under existing authority, the scoring issues remain unresolved. From the VA's perspective, the agreement was crafted with only limited, future risk to the government. The facilities were built in a highly popular section of downtown Chicago—increasing the likelihood of finding replacement tenants if demand for usage fell below initial levels. Additionally, the VA benefited, as sole beneficiary of the Trust, from proceeds from the leasing. The obligation of the Trust to the VA would help the Trust obtain funding and reduce risk from private creditors.

The VA's Chicago project is a demonstration of how a government agency was able to utilize an underdeveloped asset to fulfill an immediate need. The project was designed to limit the initial up-front cost of the venture to the initial two-year lease agreement, with construction and design of the facilities to be paid for via private equity. Future lease agreements would be entirely governed by the private trust for the 35-year agreement, with the VA receiving preferential treatment in facility usage. Utilizing the legislative authority, the VA was able to construct the optimal size facility and benefit from any private usage of the facility. The project is an example of how a PPP was used to finance and successfully create an otherwise unaffordable project.

An obstacle to greater usage of this type of funding is the budgetary treatment from the OMB and, particularly, the CBO. In 2002, HR 3947, *the Federal Property Management Reform Act*, was introduced that would give federal landholding agencies additional authorities in acquiring, managing, improving, and disposing of their property assets; it also provided incentives to manage these assets efficiently (CBO, 2002). Although the bill did not receive the necessary approval, it did clarify the position of the CBO towards PPPs. In its Cost Estimate for the Bill, the CBO stated it viewed, "hybrid entities like public-private business ventures" as

governmental. Meaning that, since the purpose of the venture is mostly or entirely governmental, any borrowing or outside financing activities would be viewed as new federal borrowing authority. Additionally, it felt that most, if not all, of the public-private ventures should be subject to the lease-purchase scoring guidelines contained in OMB *Circular A-11*.

The scoring of private involvement remains a frustrating issue as the CBO reserves the right to alter its interpretation of the scoring guidelines. For six years (1996-2002), the CBO scored military housing ventures consistently with the OMB. However, in 2002, the CBO changed its position, viewing the ventures as additional borrowing. In regards to share-in-savings contracts, the CBO reversed a decade-old policy of scoring ESPCs budget-neutral to scoring them as additional budget authority. Other agencies, such as General Services Administration (GSA), support legislation that expands the authority to utilize private partnerships (Perry, 2002, April 18). While the CBO's role is to remain objective and impartial, its interpretation of scoring guidelines dictates policy for privatization initiatives. If Congress seeks to build on the recent successes in military housing or VA's enhanced-use contracts, its members should offer directed scorekeeping that promotes efficient economic use of DoD resources. It is our belief that the efficiencies of these ventures can be translated on a larger scale to the procurement, management, and disposal of military capital equipment. The DoD can more efficiently procure and manage its assets, but only if it receives legislative authority and budgetary treatment allowing it to do so.

The decision to undertake a project must be separated into two parts:

1. Is the project worthwhile to undertake?
   a. Do the benefits exceed costs?
   b. Does the return exceed the required rate of return on investment?
   c. Does this project warrant the limited resources that it will consume?
2. Given that this project is worthwhile, what is the best method to finance the project?

ESPC Case Study

Energy Savings Performance Contracting (ESPC) is the most cost-effective means of completing building energy upgrades and associated savings. The concept has existed since 1992, but it was not implemented by the Department of Energy until 1995 (DoE, 2006, June). ESPC is a means of using utility savings to pay for all project costs. There are many possibilities of projects, such as energy-management systems, interior and exterior lighting, boiler replacement or repair of steam systems, and replacement of Heating, Ventilation, and Air Conditioning (HVAC) (Washington State Department of General Administration, 2007). This form of contracting normally guarantees project costs, savings and performance of installed equipment. However, the majority of risk is borne by the contractor, not the government. The government must fully fund the project—which often causes debate about the direct costs and overall benefit.

The Department of Energy explains:

An ESPC project is a partnership between the customer and an energy service company (ESCO). The ESCO conducts a comprehensive energy audit and identifies improvements that will save energy at the facility. In consultation with the agency customer, The ESCO designs and constructs a project that meets the agency's needs and arranges financing to pay for it. The ESCO guarantees savings sufficient to pay for

the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency. Contract terms up to 25 years are allowed. (DoE, 2006, June)

Since 2005, more than 400 federal ESPC projects, in 46 different states, by 19 different federal agencies (altogether worth $1.9 billion) have generated $5.2 billion in energy cost savings (2006, June).

The use of ESPCs is ideal for organizations which seek out alternative means of funding programs. As the Department of Defense (DoD)'s discretionary portions of the budget continue to become strained, high competition for those funds may leave critical programs dry. Many facilities throughout the DoD were built shortly after World War II. Few new facilities have been built replacing the old. Dated DoD equipment and assets—such as the B-52 bomber, SH-60 helicopter and many others—are continuously being funneled additional funds. This funding is higher than normal funding for these assets due to increased maintenance, poor fuel economy, dated insulation techniques, and lack of funding to support replacements. Thus, the DoD continues to live with existing problems. The ESPC is a means to cut costs while continuing overall functionality of facilities and assets. Other means of financing, such as PPPs and various forms of leases, are used successfully today by the private sector and will become a way of life for many organizations.

A perfect example of the benefits of an ESPC pertains to many homeowners. A homeowner will evaluate the cost of improving his/her home with the expected benefits. The homeowner may attempt to determine some form of payback period or return on investment. The homeowner must determine the means of financing such improvements as well. The government and its facilities are no different.   But many vendors are willing to offer their supplies and equipment to help defer the required payments over some time frame, but at some higher price.   Assume the proposed cost to renovate or improve a home was $10,000. This improvement would replace the windows, lighting and appliances. The home would become more efficient and reduce utility costs. The vendor and homeowner would agree upon some baseline on expenses once improvements were installed, and the difference would be used to "pay off" the vendor for its services. If there are no savings, the vendor does not get paid. Assume for contract period is eight years. Table 2 illustrates two scenarios. The first assumes the homeowner paid the vendors $10,000 up-front; then he realizes a 30% or 50% reduction in his existing $5,000 annual utility expense. The second scenario assumes the homeowner pays for the improvement in some agreed-upon ESPC with the vendors over five-years—with the same 50% reduction in annual utility expense and a 3.00% rate of inflation.

	Cost of Repair		10000	exp yr	$5,000	reduction	$1,500							
		inflation	1.03	new exp	$3,500									
		NPV	0	1	2	3	4	5	6	7	8	9	10	
30%	Scenario 1	2,795	10,000	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	
	Scenario 2	2,266	0	0	0	0		0	0	0	0	1,500	1,500	
	Vendor (30%)	530	10,000	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	0	0	
50%	Scenario 1	11,326	10,000	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	
	Scenario 2	3,776	0	0	0	0		0	0	0	0	2,500	2,500	
	Vendor (50%)	7,549	10,000	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	0	0	
	Payback period for scenario 1 would be $10,000/$1,500 which is 6.67 years.													
	There is no payback period for scenario 2 due to not making any investment into the project.													

Table 2. ESPC Scenarios

Table 2 illustrates in Scenario 1 that if the improvement is fully funded up-front in Year 0, there is a positive Net Present Value on the investment for both the 30% and 50% reductions in utility expenses. Scenario 2 demonstrates with no initial investment, a positive Net Present Value on the investment for both the 30% and 50% reductions in utility expenses. The vendor would also benefit from assisting the homeowner with the improvements. It is a win-win situation. The homeowner does not have to "fully fund" the project and achieves the same result with an alternate form of financing. Today, many private companies and local governments implement ESPCs.

Within the government and many federal agencies, there are different points of view pertaining to ESPCs and their application in the budget. The first is that ESPCs should be scored at zero because they pay for themselves. The other is that the funds must be obligated in case of contract issues such as *The Anti-deficiency Act.* *The Anti-deficiency Act*, also known as 31 USC Section 1301(a), is one of the major laws in which the Congress exercises its constitutional control of the public purse. Thus, ESPCs continue to be debated, and their role within the budget is uncertain. Yet, as demonstrated above, ESPCs are clearly a viable solution to cut costs for the DoD's facilities and assets.

The Energy Policy Act of 2005 set new federal energy goals. The act states that one goal was to "cut energy usage by 2 percent per year from 2006-2015" (DoE, 2007). The federal government may not achieve this goal without improving existing conditions at its facilities or with its equipment. The budget continues to be strained due to the Global War on Terrorism, increased health costs, a need for social security reform, and other political issues. One means to cut existing costs without having an effect on the budget is the usage of ESPCs for existing facilities and equipment. Recently, a step in the right direction was made by the Air Force. On March 1, 2007, the Air Force awarded Northrop Grumman a contract with the same principles as the ESPC. The contract was for the initial $12.5 million E-8C Joint Surveillance Target Attack Radar System (STARS) engine replacement. The contract defines the, "non-recurring engineering work required to replace engines on the E-8C Joint STARS aircraft" (Stratford, 2007). Other enhancements for the Boeing 707-based platform are scheduled with a similar contract. The Air Force decision was based on the Boeing 700-300C series aircraft refurbished by Northrop Grumman, which have performed much better than the Air Force E-8C. Thus, this has created an opportunity for the Air Force to maximize the benefits of the ESPC to improve

the E-8C's reliability, reduce maintenance costs, and make the aircraft more fuel-efficient—allowing less "in-air" refueling and allowing increased on-station time. Thus, both the contractor and the government benefit from the ESPC.

New technologies, especially energy-saving advancements, should be used when feasible in a world where prices continue to rise as resources continue to become scarce. United States companies should be provided an incentive to explore new technologies and processes to innovate and create savings which not only help them, but improve the efficiency of the government and, thus, benefit the taxpayer. If such were the case, ultimately the productivity of our country would increase, resources would be conserved, and the economy would grow while helping fund our government.

Conclusions and Recommendations

Recommendations

This research addressed only a limited number of the total available options to finance a capital asset. All factors being equal, the time-value of money dictates that payment of an asset up-front will necessarily be less costly than delayed payment. However, the analysis presented here has hopefully addressed several scenarios in which government agencies would be able to leverage their available resources and incorporate the private sector via some form of Public-private Partnership to achieve a cost-effective alternative to up-front funding. The current scoring guidelines in OMB *Circular A-11* provide a negative bias towards using alternative approaches to full-funding. In many cases, agencies are forced to seek alternative funding measures or do without the asset. Several recommendations to modify the current budget-scoring process and scoring guidelines in an attempt to promote improved economic efficiency in public projects are presented below.

Scoring of Leasing

The crucial question in categorizing a lease is determining what constitutes purchase of an asset. Long-term leases that provide the government with ownership of the asset are scored up-front in an amount equal to the net present value of the future lease payments for the asset. Conversely, leases that provide the government with only partial use of the asset's economic life can be scored in annual obligations as an operating lease (CBO, 2003, p.viii). The scorekeepers apply strict criteria in determining between an operating or capital lease. The result, and intent of the guidelines, is that almost all DoD equipment is acquired via purchase or capital leases. The OMB guidelines for operating leases have two additional requirements to the four basic criteria used by the Federal Accounting Standards Board (FASB). These two requirements include:

1. There is a private-sector market for the asset.

2. The asset is a general-purpose asset rather than being for a special purpose of the government and is not built to the unique specification of the government as lessee (OMB, 2006, June, pp. 3-4).

These two rules are specifically designed to eliminate operating leases as a financing option for the procurement of military equipment.   Table 3 outlines the criteria for Public vs. Private-Operating-Lease determination.

OMB Requirements to be Considered an Operating Lease (Public)	Basic Criteria in Lease Determination (Private)
(OMB, 2006, June, pp. 3-4)	(Lee, 2003, pp. 10-11)
Ownership of the asset remains with the lessor during the term of the lease and is not transferred to the Government at or shortly after the end of the lease period.	The lease transfers ownership of the property to the lessee by the end of the lease term.
The lease does not contain a bargain-price purchase option.	The lease contains an option to purchase the leased property at a bargain price.
The lease term does not exceed 75% of the estimated economic lifetime of the asset.	The lease term is equal to or greater than 75% of the estimated economic life of the leased property.
The present value of the minimum lease payments over the life of the lease does not exceed 90% of the fair market value of the asset at the inception of the lease.	The present value of rental and other minimum lease payments, excluding that portion of the payments representing executory costs, equals or exceeds 90% of the fair value of the leased property.
The asset is a general purpose asset rather than being for a special purpose of the Government and is not built to unique specification for the Government as lessee.	
There is a private-sector market for the asset.	

Table 3. Public vs. Private Operating Lease Determination

The stricter guidelines were adopted in 1991 in response to the frequent use of lease-purchases in the 1980s to acquire assets, including propositioned ships or buildings. The CBO cited four major concerns of the increased use of leasing that helped inspire the new guidelines. It asserts that leasing has the ability to:

1. Reduce the budget's ability to fully depict the Federal Government's financial commitments;

2. Undermine fiscal policy by circumventing controls such as limits on deficits and caps on discretionary spending;

3. Allow an agency to avoid facing the full costs of purchasing an asset at the time it decides to buy it, thus making acquisitions that are not cost-effective more likely; and

4. Raise the costs of some investments because a lease-purchase is, over the life of an asset, inherently more costly to the government than a direct purchase (CBO, 2003, p. ix).

We propose to limit the guidelines to the four basic criteria accepted in the private sector with one additional caveat. A fifth guideline would include a proposal that highlighted the following issues:

1. The estimated total use (years) of the asset by the government.

2. The reason as to why operating leasing would be preferred over direct-purchase, lease-purchase or other type of financing.

3. Explicitly address ownership options for the asset. Also discuss the probability the asset would be damaged in its use and ultimately be required to be purchased.

4. Salvage value for the asset at completion of the lease—discussing any outside markets for the asset to determine potential market value.

The proposal would be submitted to the OMB, CBO, and Congressional Budget Committees as part of the legislative process. If these new guidelines for operating leases were adopted, greater flexibility would be restored to the DoD in financing its requirements. The guidelines would not hinder Congress's ability to allocate financial resources effectively.

Scoring of Alternative Financing

Alternative financing consists of almost any financing option or combination of options that can be used in lieu of conventional full-funding. The private sector has metrics such as profit or stock price that help motivate corporate executives in their selection of the most beneficial financing method for their company. Without these incentives, the federal budget process remains a delicate balance between agency needs and Congressional control of the purse. Current scoring guidelines are designed to provide the decision-makers in Congress with the most informative representation of current and future government obligations. The legislation also has the effect of biasing full-funding versus other forms of financing. Yet, in certain situations, the needs and resources of the government can be combined with the capabilities of the private sector to form a partnership that is beneficial to both parties. Public-private Partnerships represent the most practical financing method available that harnesses these capabilities and addresses the needs of the DoD.

Unfortunately, the financial details of Public-private Partnerships are typically unique and involve complex financial relationships, causing few useful precedents to be available to help predict the scoring outcome. The National Council for Public Private Partnerships (NCPPP) cites one of the major impediments in the budget scoring policy to be the ambiguity surrounding the current scoring guidelines (2007). The OMB scoring rules represent policy vice actual hard-fast rules and are intentionally vague to allow interpretation by the CBO or OMB. Reviewing the scoring determination through an open forum between concerned policies would not only clarify the intent of the rules, but also improve adherence to the scoring rules. The Council also asserts that scoring confusion could further be eliminated if an "Alternative Financing" committee was formed by the OMB to assist agencies that seek private-sector involvement (2007). The committee can be established independently from the OMB to eliminate any conflicts of interests or questions of neutrality.

Additionally, the scoring process would be improved if the scoring rules placed greater emphasis on economic efficiency rather than the determination of outlays. For instance, share-in-savings contracts that have outlays resulting only from the net savings to the government should be scored as budget neutral or have some other discount factor that reflects the financial benefits of the deal. Public-private Partnerships are particularly penalized in this manner as many benefits from these ventures do not have an explicit value that can be readily estimated. The inability to easily or accurately estimate these benefits causes them to be ignored in the scoring process. In these cases, representatives from the prospective Alternative Financing committee could provide their best estimate of the projected savings of private involvement—either by discounting the budget authority scored for the project or by including this dollar amount independent of the scoring estimate. In either manner, Congress would be informed of the benefits of the alternative financing. The current scoring rules are overly conservative and neglect to include the majority of the benefits of PPP in scoring budget authority.

Conclusion

The consistency and transparency in the budget process that were the intent of the scoring guidelines also have the affect of altering the feasibility of alternative financing ventures. Currently, there are many opportunities to improve the aging infrastructure and reduce the lifecycle costs of a project through greater private-sector involvement. A major impediment to realizing this goal is the interpretation of the scoring guidelines by the CBO and OMB and the absence of legislation authorizing such private-sector participation. The government would benefit from either a revision to the current scoring guidelines or a more comprehensive interpretation of the current scoring rules. We assert that if these changes are implemented, then the soldiers and sailors in the field would have a better probability of being provided the equipment necessary to complete their National Security mission at a time when we are faced with ever-shortening supply of money during the Global War on Terrorism.

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Panel 12 – Considerations in Making Logistics Support Choices for Weapon Systems

Thursday, May 17, 2007	Panel 12 - Considerations in Making Logistics Support Choices for Weapon Systems
9:30 a.m. – 11:00 a.m.	**Chair:** **Reuben S. Pitts III,** Head, Warfare Systems Department, NSWC Dahlgren Division **Discussant:** **David Lamm**, Associate Professor emeritus, Naval Postgraduate School **Papers:** ***Outsourcing for Optimal Results: Six Ways to Structure an Evaluation of Alternatives*** **Francois Melese**, Naval Postgraduate School ***Alternative Strategies for Managing MK48 Intermediate Maintenance Activity*** **William Lucyshyn**, University of Maryland

Chair: Reuben S. Pitts III, Head, Warfare Systems Department, NSWC Dahlgren Division

Discussant: David Lamm, Professor Emeritus from the Graduate School of Business and Public Policy (GSBPP), served at NPS as both a military and civilian professor from 1978 through his retirement in January 2004, teaching a number of acquisition and contracting courses, as well as advising thesis and MBA project students. During his tenure, he served as the Academic Associate for the Acquisition & Contract Management (815) MBA Curriculum, the Systems Acquisition Management (816) MBA Curriculum, the Master of Science in Contract Management (835) distance learning degree, and the Master of Science in Program Management (836) distance learning degree. He created the latter three programs. He also created the International Defense Acquisition Resources Management (IDARM) program, which brings acquisition education in-country to over 20 allied nations. Further, he created the Advanced Acquisition Program (AAP), a distance learning certificate program for the civilian acquisition workforce throughout the country. Finally, in collaboration with the GSBPP Acquisition Chair, he established and served as PI for the Acquisition Research Program, including inauguration of an annual Acquisition Research Symposium. He also developed the Master of Science in Procurement & Contracting degree program at St Mary's College in Moraga, CA, and served as a Professor in both the St Mary's and the George Washington University's graduate programs.

He has researched and published numerous articles and has written an acquisition text entitled *Contract Negotiation Cases: Government and Industry, 1993*. He served on the editorial board for the *National Contract Management Journal* and was a founding member of the editorial board for *the Acquisition Review Quarterly*, now known as the *Defense Acquisition Review Journal*. He served as the NPS member of the Defense Acquisition Research Element (DARE) from 1983-1990.

Prior to NPS, he served as the Supply Officer aboard the USS Virgo (AE-30) and the USS Hector (AR-7). He also had acquisition tours of duty at the Defense Logistics Agency in Contract Administration and the Naval Air Systems Command where he was the Deputy Director of the Missile Procurement Division.

He holds a BA from the University of Minnesota and a MBA and DBA both from The George Washington University. He is a Fellow of the National Contract Management Association and received that association's Charles A. Dana Distinguished Service Award and the Blanche Witte Award for Contracting Excellence. He created the NCMA's Certified Professional Contracts Manager (CPCM) Examination Board and served as its Director from 1975-1990. He is the 1988 NPS winner of the RADM John J. Schieffelin Award for Teaching Excellence.

Outsourcing for Optimal Results: Six Ways to Structure an Evaluation of Alternatives

Presenter: Francois Melese, PhD, joined the NPS faculty in 1987. He earned his undergraduate degree in Economics at UC Berkeley, his Master's at the University of British Columbia in Canada, and his PhD at the Catholic University of Louvain in Belgium. After five years as a faculty member in the Business School at Auburn University, Francois joined NPS as part of the Defense Resources Management Institute (DRMI). In his time at NPS, he has taught public budgeting and defense management in over two dozen countries and has published over 50 articles and book chapters on a wide variety of topics. More recently, at the request of the State Department and NATO Headquarters, he has represented the US at NATO Defense meetings in Hungary, the Ukraine, Germany and Armenia. His latest article (co-authored with Jim Blandin and Sean O'Keefe) appeared in the *International Public Management Review*. The article (available at www.ipmr.net) is entitled "A New Management Model for Government: Integrating Activity-Based Costing, the Balanced Scorecard and Total Quality Management with the spirit of the Planning, Programming and Budgeting System."

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Abstract

This study presents six ways to structure an evaluation of alternative outsourcing opportunities. According to the Office of Management and Budget's (OMB) Circular A-76, the decision to outsource government positions or functions involves a comparison of "bids" or "proposals"—Invitations for Bids (IFB) for well-defined, routine commercial activities; Requests for Proposals (RFP) for more complex, more difficult to define activities. The paper suggests replacing the conventional decision sciences approach that currently dominates defense guidance, with a more intuitive constrained optimization approach borrowed from economist's "characteristics approach to demand theory." One of the key insights derived from the economic approach is that alternatives are generated as part of a two-step optimization and appear as (response) functions and not points in Cost-Effectiveness space. One important implication is that what have previously been viewed as dominated (inferior) alternatives may prove to be superior under different budget scenarios. The study discusses concepts of intra- and inter-program analysis, cost as an independent variable, expansion paths, "knees of the curve," and opportunity costs, and offers an intuitive discussion of the hazards of applying cost/effectiveness ratios to rank alternatives. In the spirit of government competitions, anyone that discovers another constrained optimization approach to structure a cost-effectiveness analysis of alternative outsourcing opportunities will receive a cash award of $100 from the author.

Alternative Strategies for Managing MK48 Intermediate Maintenance Activity

Presenter: William Lucyshyn is the Director of Research and a Senior Research Scholar at the Center for Public Policy and Private Enterprise in the School of Public Affairs at the University of Maryland. In this position, he conducts research on the public policy challenges posed by the increasing role information technologies play in both the public and private sectors.

Previously, Mr. Lucyshyn was a member of the Senior Executive Service and served as a program manager and the principal technical advisor to the Director, Defense Advanced Research Projects Agency (DARPA), on the identification, selection, research, development, and prototype production of advanced technology projects. Prior to this appointment, Mr. Lucyshyn completed a 25-year career in the US Air Force, serving in various special operations and acquisition positions.

He received his Bachelor Degree in Engineering Science from the City University of New York in 1971. In 1985, he earned his Master's Degree in Nuclear Engineering from the Air Force Institute of Technology. He was certified Level III, as an Acquisition Professional in Program Management in 1994.

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Abstract

Since 1972, Sailors have delivered more than 10,000 MK48[1] torpedoes to Pacific Fleet submarines. During that 29-year period, the IMA achieved numerous awards and earned a reputation for outstanding torpedo reliability. Manning shortfalls in the Navy's torpedo-man rating drove the decision to outsource production to the private sector. In 2001, the MK48 torpedo Intermediate Maintenance Activity (IMA) at Pearl Harbor was outsourced to a contractor team led by Raytheon. All but two of the 181 military billets that existed at the IMA were reallocated to other critical areas.

Outsourcing is a management strategy that contracts out organizational activities to vendors or suppliers who specialize in these activities in order to perform them more efficiently. Outsourcing or "contracting out" still requires the government to remain fully responsible for the provision of all services and management decisions. If implemented correctly, outsourcing can be used to introduce competitive pressure. This pressure generally incentivizes performance improvements and cost reductions.

This case study will compare the operation of the Pearl Harbor IMA with that of the Navy Submarine Torpedo Facility IMA, Yorktown, which is still manned primarily by active-duty sailors.

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[1] The Mark 48, in production since 1972, is a heavyweight torpedo still carried on all US submarines and designed to detonate on contact or in proximity to a target.

Panel 13 - Considerations for Acquisition Process Improvements

Thursday, May 17, 2007 9:30 p.m. – 11:00 a.m.	**Panel 13 - Considerations for Acquisition Process Improvements**
	Chair:
	Dr. Nancy L. Spruill, Director, Acquisition Resources and Analysis, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics)
	Papers:
	Review of Defense Acquisition Structures & Capabilities
	Paul Alfieri and **Mark D. Lumb**, Defense Acquisition University
	An Integrated Portfolio Management Approach to Weapon System Investments Could Improve DoD's Acquisition Outcomes
	Katherine Schinasi, US Government Accountability Office
	DoD Contract Termination Liability: An Analysis of Special Termination Cost Clause (STCC)
	Rene Rendon and **John Mutty**, Naval Postgraduate School

Chair: Dr. Nancy L. Spruill, Director, Acquisition Resources and Analysis, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), received her Bachelor of Science degree in Mathematics, in 1971. From 1971 to 1983, she held a variety of positions with the Center for Naval Analyses, including Technical Staff Analyst, Professional Staff Analyst and Project Director. She earned her Master of Arts in Mathematical Statistics in 1975 followed by her Doctorate in 1980.

Dr. Spruill served on the staff of the Office of the Secretary of Defense from 1983 to 1993. Initially, she was the Senior Planning, Programming, and Budget Analyst in the Manpower, Reserve Affairs and Logistics Secretariat. Later, she served as the Director for Support and Liaison for the Assistant Secretary of Defense for Force Management and Personnel. Then she served as the Senior Operations Research Analyst in the Office of the Assistant Secretary of Defense for Program Analysis and Evaluation.

In 1993, she joined the staff of the Defense Mapping Agency (DMA), serving as the Chief of Programs and Analysis Division for the DMA Comptroller. Her role included oversight of the Agency's $800M program. Subsequently, she served as Acting Deputy Comptroller and was a member of the Reinvention Task Force for the Vice President's National Performance Review. Her reengineering work was implemented and resulted in a mapping organization that is customer focused and reduced in the management layers from eleven to three.

In March 1995, she was selected as the Deputy Director for Acquisition Resources for the Under Secretary of Defense for Acquisition and Technology (USD(AT&L)). In February 1999, she was appointed Director, Acquisition Resources & Analysis (ARA) for USD(AT&L). In this capacity she is responsible for the coordination of all defense acquisition and technology planning, programming, and budgeting process activities, as well as funds control, Congressional actions in the authorization and appropriations processes, and special analyses for the Under Secretary. She also manages the studies program for OSD and oversees USD(AT&L)'s office automation system and manages its information system network.

Dr. Spruill has been a member of the Senior Executive Service since 1995. She is a certified Acquisition Professional and an active member of the American Statistical Association. Her many honors and awards include the Defense Medal for Exceptional Civilian Service, the Defense Medal for Meritorious Civilian Service, and the Hammer Award. She has contributed papers in publications of the statistics and defense analyses communities and authored articles in the general press on how politicians use - and abuse - statistics.

Review of Defense Acquisition Structures & Capabilities

Presenter: Paul Alfieri, Defense Acquisition University, graduated from the United States Naval Academy, Annapolis, MD, in June, 1969. He completed Navy flight training in November, 1970, and was designated a naval aviator.   Dr. Alfieri served 24 years in the US Navy, in which he was a helicopter pilot and an Aeronautical Engineering Duty Officer. While in the Navy, he earned a Master's degree in Aeronautical Engineering from the Naval Postgraduate School in Monterey, CA, in 1977. Dr. Alfieri spent 8 years at the Naval Air Systems Command and became an acquisition specialist there. At NAVAIR, Dr. Alfieri was a Deputy Program Manager (HARM missile) and Program Manager (F404 engine). Since leaving the Navy, he completed studies for his doctorate in Education at Virginia Tech in Blacksburg, VA, in 1998. For the last 16 years, he has been on the faculty of the Defense Acquisition University, where he has served as Department Chair of the Test & Evaluation Department and is currently the Director of Research. In 2002, Dr. Alfieri graduated from the Industrial College of the Armed Forces (ICAF) in Washington, DC, with a Master's degree in National Security Affairs.

Author: Mark D. Lumb, Defense Acquisition University, graduated from the University of Notre Dame, South Bend, Indiana, in May of 1982.   He completed the Infantry Officer Basic Course at Ft Benning, GA, and was assigned as Second Lieutenant to a reinforced heavy brigade in southern Germany. Lumb spent the next 10 years in various Infantry assignments, alternating between Mechanized and Light Infantry Divisions.   In 1991, he transition from the Infantry Branch to the newly formed Army Acquisition Corps, spending the remainder of his Army career in various acquisition assignments, including anti-tank missiles, ground robotics and rotary-winged aircraft. While in the Acquisition Corps, he earned a Master's Degree in Acquisition and Contract Management from the Naval Postgraduate School, Monterey, CA, in 1991.   Lumb culminated his Army Acquisition career as the inaugural Program Manager of the Army's UH-60M, Blackhawk helicopter improvement program. After retiring from the Army in 2002, Lumb joined the Defense Acquisition University where he served as a member of the faculty in the Acquisition Program Management Department and, most recently, in his current position as the Director of Program Development.

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Abstract

The Department of Defense (DoD) Acquisition Process has been the subject of many reform initiatives and improvement attempts over the last several decades. The acquisition process is deliberately structured for oversight (checks and balances) and decentralized control. Separate, independent offices/staffs within the DoD make requirements determination, resource allocations, and programmatic decisions (milestone decisions). Coupled with inter-service competition for missions and dollars, this process involves stakeholders with competing interests and is certainly not designed for efficiency. Rapid growth in technology, foreign competition for military systems, and changing threats further exacerbate the problem. The

results can usually be categorized as: too many requirements, too many programs, unstable budgets, insufficient funds, ever-changing requirements.

Most stakeholders in the process have much to gain and much to lose. Whether we talk in terms of political dominance, global power, military deterrence or maximization of budget share, the stakes of the game are very high. This fact is certainly not lost on Congress. In *Public Law `109-163*, *FY06 National Defense Authorization Act* (Section 814), Congress directed the Defense Acquisition University (DAU), acting under the direction and authority of USD(AT&L), to conduct a major review of all DoD acquisition organizations. From this legislation, it appears that Congress desires more control over the acquisition process and, more importantly, improved acquisition outcomes.

While conducting the Defense Acquisition Structures & Capabilities Review, the DAU was asked to specifically examine the structure of the DoD's acquisition organizations and to address the capabilities and capacities that acquisition organizations require to successfully discharge their acquisition missions. This study will provide an additional examination of capability shortfalls and gaps, along with appropriate recommendations for reform and improvement.

Employing a survey-instrument methodology, utilizing both written responses and face-to-face interviews, and gathering data from the Military Departments, the Defense Agencies, Field Operating Activities and numerous key leaders throughout the Department of Defense, this paper will attempt to explore the relationship between organizational re-structuring, acquisition capabilities and capacities, and positive acquisition outcomes.

An Integrated Portfolio Management Approach to Weapon System Investments Could Improve DoD's Acquisition Outcomes

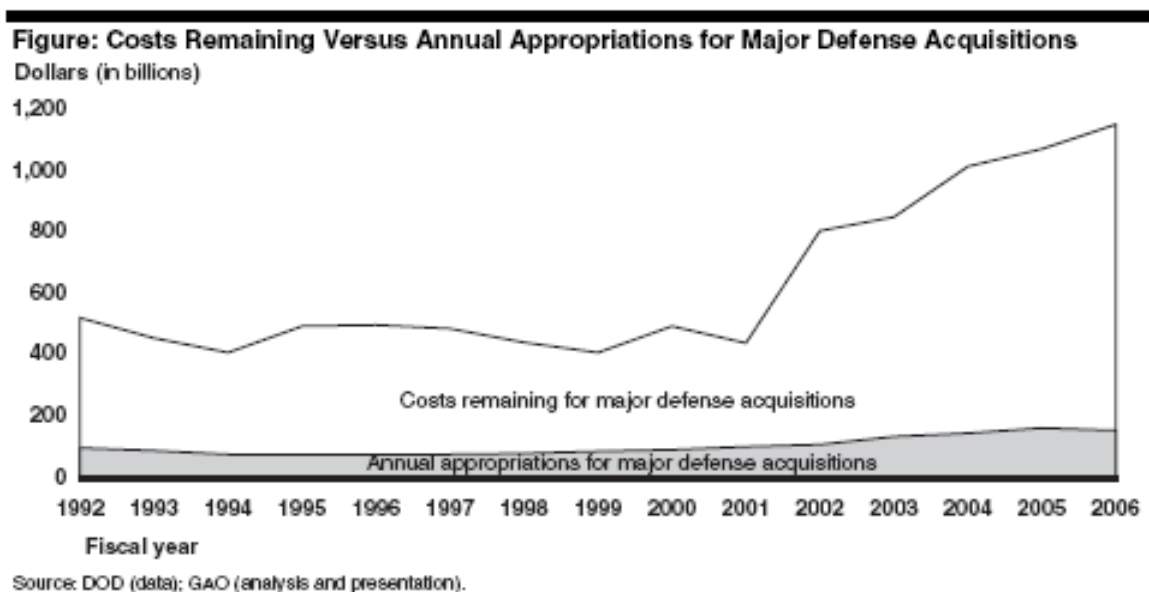**Presenter: Katherine Schinasi**, US Government Accountability Office

What GAO Found

To achieve a balanced mix of executable development programs and ensure a good return on their investments, the successful commercial companies GAO reviewed take an integrated, portfolio management approach to product development. Through this approach, companies assess product investments collectively from an enterprise level, rather than as independent and unrelated initiatives. They weigh the relative costs, benefits, and risks of proposed products using established criteria and methods, and select those products that can exploit promising market opportunities within resource constraints and move the company toward meeting its strategic goals and objectives. Investment decisions are frequently revisited, and if a product falls short of expectations, companies make tough go/no-go decisions. The companies GAO reviewed have found that effective portfolio management requires a governance structure with committed leadership, clearly aligned roles and responsibilities, portfolio managers who are empowered to make investment decisions, and accountability at all levels of the organization.

In contrast, DOD approves proposed programs with much less consideration of its overall portfolio and commits to them earlier and with less knowledge of cost and feasibility. Although the military services fight together on the battlefield as a joint force, they identify needs and allocate resources separately, using fragmented decision-making processes that do not allow for an integrated, portfolio management approach like that used by successful commercial companies. Consequently, DOD has less assurance that its investment decisions address the right mix of warfighting needs, and, as seen in the figure below, it starts more programs than current and likely future resources can support, a practice that has created a fiscal bow wave. If this trend goes unchecked, Congress will be faced with a difficult choice: pull dollars from other high-priority federal programs to fund DOD's acquisitions or accept gaps in warfighting capabilities.

Figure: Costs Remaining Versus Annual Appropriations for Major Defense Acquisitions

Dollars (in billions)

Source: DOD (data); GAO (analysis and presentation).

Figure 1. Costs Remaining vs. Annual Appropriations for Major Defense Acquisitions

Why GAO did this Study

Over the next several years, the Department of Defense (DOD) plans to invest $1.4 trillion in major weapons programs. While DOD produces superior weapons, GAO has found that the department has failed to deliver weapon systems on time, within budget, and with desired capabilities. While recent changes to DOD's acquisition policy held the potential to improve outcomes, programs continue to experience significant cost and schedule overruns.

GAO was asked to examine how DOD's processes for determining needs and allocating resources can better support weapon system program stability. Specifically, GAO compared DOD's processes for investing in weapon systems to the best practices that successful commercial companies use to achieve a balanced mix of new products, and identified areas where DOD can do better. In conducting its work, GAO identified the best practices of: Caterpillar, Eli Lilly, IBM, Motorola, and Procter and Gamble.

What GAO Recommends

GAO is making several recommendations for DOD to implement an integrated portfolio management approach to weapon system investments. DOD stated that it is undertaking several pilot efforts to improve the department's approach and that implementation of any new business rules will be contingent upon the outcomes of these efforts.

www.gao.gov/cgi-bin-getrpt?GAO-07-388

To view the full product, including the scope and methodology, click on the link above. For more information, contact Michael J. Sullivan at (202) 512-4841 or sullivanm@gao.gov.

DoD Contract Termination Liability: An Analysis of Special Termination Cost Clause (STCC)

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Abstract

The specific purpose of the research was to review current policies, practices, and procedures for funding and managing Contract Termination Liability within the Department of Defense (DoD). The research proposes alternative approaches for improving the DoD's ability to manage Contract Termination Liability and discusses the resulting effect of each alternative on defense acquisition practices. First, we provide a brief review of regulatory and policy guidance on Contract Termination Liability as reflected in the *Federal Acquisition Regulation* (*FAR*) and the *Financial Management Regulations* (*FMR*). We then discuss the current practices and procedures for funding and managing Contract Termination Liability. Next, we present program management challenges and observations and findings based on our research of current Contract Termination Liability policies and real-world practices. A discussion of alternative approaches to funding Contract Termination Liability is then presented, including the use of Special Termination Cost Clauses (STCC). Finally, this research concludes with a summary and recommendations on how the DoD could improve the policies and practices for managing Contract Termination Liability.

A copy of the complete report is available at the following website: www.acquisitionresearch.org: Report Number NPS-CM-06-042

Executive Summary

This research paper explores the Department of Defense (DoD) policies and practices for managing Contract Termination Liability. The specific purpose of the research was to review current policies, practices, and procedures for funding and managing Contract Termination Liability within the DoD. Alternative approaches for improving the DoD's ability to manage Contract Termination Liability are proposed and the resulting effect of each alternative on defense acquisition practices is discussed. Recommendations on how the DoD could improve the policies and practices for managing Contract Termination Liability are provided.

This research found that the regulations and policies pertaining to the management and funding of Contract Termination Liability are inconsistent and subject to interpretation. Program managers, finance and budget managers, and contracting officers have differing interpretations of the requirement for funding Contract Termination Liability. Furthermore, the practices and procedures used in defense acquisition program offices reflect this inconsistency.

A review of current practices and procedures for funding and managing Contract Termination Liability and historical data of past contract terminations found that the probability of a contract termination for convenience is very small, and program managers' approaches to managing Contract Termination Liability reflects this probability. The normal procedure for handling the potential liability associated with a contract terminated for convenience is to "budget" for the liability. Then, in coordination with the contractor, the required amount of funding is tracked on a regular basis. In this case, budgeting for Termination Liability does not mean obligating funds specifically for that purpose.

Interviews with various acquisition program offices indicate that program managers are generally satisfied with the current method for managing Contract Termination Liability because the procedure they currently use allows them to keep all of the funding appropriated for their program. Furthermore, program managers are not in favor of a "tax" that would negate the requirement to budget for Contract Termination Liability. A tax would deprive them of funds that they currently have at their disposal. Additionally, if all programs were taxed, there is a general concern that the pooled funds would likely be lost—either the Military Departments (or DoD) would use them to solve other problems if they were not required to cover a liability, or Congress would look upon the funds that had been set aside as a "slush fund," making them tempting for other uses.

Interviews also indicated that support for increased use of STCCs is not evident, either at the program level or the OMB or Congressional level. Congress has expressed its concern through report language. OMB correspondence has indicated that support for more than one STCC per service is unlikely. However, it should be noted that those programs that have significant funding problems and/or are concerned about the possibilities of termination do support additional use of STCCs. In fact, these programs would prefer to have a STCC that covers more cost elements than the standard STCC.

Finally, this research concluded with the following recommendations for the DoD's management of Contract Termination Liability: 1. Remove the ambiguity and improve the consistency in the regulations pertaining to the management of Contract Termination Liability; 2. Refrain from imposing a tax system to provide funding for potential Contract Termination Liability, and 3. Continue to use STCCs for the larger programs with funding or longevity concerns.

Regulatory and Policy Guidance

This section of the research report focuses on the regulatory and policy guidance on Termination Liability and the Special Termination Cost Clause (STCC). The regulatory and policy guidance covering Termination Liability (and, specifically, Special Termination Cost Clauses (STCC)) is found in the DoD *Financial Management Regulation* (*FMR*) and the *Defense Federal Acquisition Regulation Supplement* (*DFARS*). In addition, the Air Force *Financial Management Regulation* is also discussed as an example of Agency-specific guidance on contingent liability.

Termination Liability

The DoD *Financial Management Regulation* (*FMR*) defines Termination Liability as:

The amount of prepayments that cover payments required by the contract, and any damages and costs that may accrue from the cancellation of such contract. Funds prepaid for Termination Liability will convert to cover actual expenditures in the event that the contract not be terminated prior to performance completion. Termination Liability may not apply to articles/services provided under other authorities of the Foreign Assistance Act or AECA. (DoD, 2006c, Vol. 15)

The *Financial Management Regulation* (*FMR*) categorizes Contingent Liabilities (CLs) as probable, possible, or remote (DoD, 2006c). The terms probable, reasonably possible, and remote identify three areas within that range as follows:

1. Probable: The future event or events are likely to occur.

2. Reasonably possible: The chance of the future event or events occurring is more than remote but less than likely.

3. Remote: The chance of the future event or events occurring is slight.

Probable CLs must be covered by a commitment of funds. Probable CLs are most likely to become actual liabilities. Commitments are not required for possible CLs and should not be established for remote CLs (DoD, 2006c, Vol. 4, Ch. 13, pp. 241-242).

The budgeting for Contingent Liabilities is discussed in the following excerpts taken from the DoD *Financial Management Regulation*:

Special Provisions for Determining the Amounts of Commitments

Contingent Liabilities Remaining Under Outstanding Contracts. There are contingent liabilities for price or quantity increases or other variables that cannot be recorded as valid obligations in the cases of (1) outstanding fixed-price contracts containing escalation, price redetermination, or incentive clauses, or (2) contracts authorizing variations in quantities to be delivered, or (3) contracts where allowable interest may become payable by the US Government on contractor claims supported by written appeals pursuant to the "Disputes" clause contained in the contract (see subparagraph 080202.D, below). Amounts to cover these contingent liabilities should be carried as outstanding commitments pending determination of actual obligations. The amounts of such contingent liabilities, however, need not be recorded at the maximum or

ceiling prices under the contracts. Rather, amounts should be committed that are estimated conservatively to be sufficient to cover the additional obligations that probably will materialize, based upon judgment and experience. In determining the amount to be committed, allowances may be made for the possibility of downward price revisions and quantity underruns. Each contingent liability shall be supported by sufficient detail to facilitate audit. (DoD, 2006c, Vol. 3, Ch. 8, para. 080202)

Budgeting for Termination Liability on Incrementally Funded RDT&E Contracts

The legal requirements of the *Anti-deficiency Act* and the long-standing policy of not committing a successor Congress to a course of action both make it necessary that the unliquidated obligation for an incrementally funded, multiple-year contract be sufficient at all times to cover the cost of terminating that contract for the convenience of the Government.

Budgeting to cover Termination Liability will not increase the total amount budgeted for the program. It will require that the distribution of funds by fiscal year be shifted more towards the earlier years of the contract than if funds had been budgeted only to cover the actual bill to be paid each year. The distribution of funds by fiscal year shall be such that, if a contract is terminated at any point during the fiscal year, all termination costs can be financed from the unliquidated obligation on the contract without recourse to reprogramming of funds, supplemental appropriations, or awaiting the appropriation of funds for the succeeding fiscal year's funding increment. All programs shall adhere to this policy with the following two exceptions, both of which are to be used rarely.

   a. Special Termination Cost Clause (STCC). DoD *FAR* Parts 249.50170 and 252.249-7000 permit the use of STCC in fixed-price incentive contracts and incrementally funded cost reimbursement contracts. If contracts containing an STCC are terminated before completion, the special termination charges are covered by the unobligated balance of the applicable appropriation, subject to any congressional approval required for reprogramming. The extent to which the STCC can be used is limited to the ability of the Service or Agency to cover expected termination costs from unobligated balances. A recordable obligation under the STCC arises when the contract is actually terminated. If a proposed STCC would require an above-threshold reprogramming action when a program is terminated, the approval to use the STCC shall be obtained from the USD (Comptroller) before the contract or contract modification is awarded. All STCCs, regardless of dollar amount, require prior notification of the House and Senate Appropriations Committees.

   b. Statutory Waivers. The Department is not required to budget for, or obligate funds sufficient to cover, Termination Liability in connection with an incrementally funded RDT&E contract if Congress has expressly exempted the program or contract from that requirement. When this situation arises, however, the budget exhibits for the program shall clearly indicate the value of the unfunded Termination Liability by year for the current year, budget year, and the outyears covered by the FYDP. (DoD, 2006c, Vol. 2A, Ch. 1, para. 010214)

Termination Liability is considered a contingent liability since adequate funds must be committed to cover the liabilities resulting from the termination of contracts, including any potential or Contingent Liabilities (Gill, 2003).

The DoD *FMR* explains Contingent Liabilities as follows:

Contingent Liability—The term has two meanings. As a budgetary term, it represents variables that cannot be recorded as valid obligations. Such variables include (1) outstanding fixed-price contracts containing escalation, price redetermination, or incentive clauses, or (2) contracts authorizing variations on quantities to be delivered, or (3) contracts where allowable interest may become payable by the US Government on contractor claims supported by written appeals pursuant to the "DISPUTES" clause contained in the contract. As a proprietary accounting term, it represents an obligation, relating to a past transaction or other event or condition that may arise in consequence, as a future event now deemed possible but not probable. When the liability is determined to be possible, but not probable, the potential liability is disclosed as a footnote to the financial statements. When the potential liability becomes probable, it is recorded in the accounts as a current liability or a reduction of an asset. The budget definition is the preferred usage. (DoD, 2006c, Vol. 15)

Thus, according to DoD *FMR*, Volume 2A, Chapter 1, "all termination costs can be financed from the unliquidated obligation on the contract without recourse to reprogramming of funds, supplemental appropriations, or awaiting the appropriation of funds for the succeeding fiscal year's funding increment" (2006c). The two exemptions to this are a Special termination Cost Clause (STCC) and a Statutory Waiver.

In addition, Volume 3, Chapter 8, Section 080512 of the DoD *FMR* states that in the case of termination of a contract, the contract shall be decreased to an amount that is sufficient to meet the settlement costs under the termination.

The Air Force Material Command (AFMC) *Financial Management Reference System* (2005, February) provided more detailed guidance on funding termination costs. The AFMC *FMRS* states the following concerning funding termination costs:

The funded activity should commit the estimated funds to cover the expected contingent liability (CL). This estimated CL amount is in excess of the contract awarded amount recorded as an obligation. The financial manager must record commitments for CLs against the applicable FY and appropriation cited on the contract. Normally, funds for CLs are maintained locally. Funds are committed for a contingent liability at the time of contract award, based on the amount provided by the contracting officer [...]. Commitments are not recorded for STCC or contingent termination liabilities. Obligations are recorded when the action to terminate is taken. (AFMC, 2005, February)

The AFMC *FMRS* further states that funds are committed for all "probable" CLs (funding for "possible" or "remote" CLs is not necessary) as defined in a matrix. "The CL Matrix is used to identify, categorize according to probability, and track CLs throughout the life of a contract [...] must be reported to SAF/FM semi-annually" (AFMC, 2005, February).

As indicated above, the DoD *FMR* refers to two exceptions to the policy of budgeting for Termination Liability. These include the Special Termination Cost Clause (STCC) and the Statutory Waiver. These will be discussed below.

Special Termination Cost Clause (STCC)

Regulatory and policy guidance related to the use of Special Termination Cost Clauses is found in the DoD *FMR* (Section: "Budgeting for Termination Liability on Incrementally Funded RDT&E Contracts," p. 3) and the DoD *FAR*.

Although the *Federal Acquisition Regulation* (*FAR*) Part 49 provides guidance on contract terminations, the *Defense FAR Supplement* (*DFARS*) provides the guidance and prescribes the clause specifically for Special Termination Costs. The *DFARS* guidance at 249.501-70 states the following:

249.501-70 Special Termination Costs.

(a) The clause at 252.249-7000, Special Termination Costs, may be used in an incrementally funded contract when its use is approved by the agency head.

(b) The clause is authorized when—

    (1) The contract term is two years or more;

    (2) The contract is estimated to require—

        (i) Total RDT&E financing in excess of $25 million; or

        (ii) Total production investment in excess of $100 million; and

    (3) Adequate funds are available to cover the contingent reserve liability for special termination costs.

(c) The contractor and the contracting officer must agree upon an amount that represents their best estimate of the total special termination costs to which the contractor would be entitled in the event of termination of the contract. Insert this amount in paragraph I of the clause.

(d)   (1) Consider substituting an alternate paragraph I for paragraph I of the basic clause when—

        (i) The contract covers an unusually long performance period; or

        (ii) The contractor's cost risk associated with contingent special termination costs is expected to fluctuate extensively over the period of the contract.

    (2) The alternate paragraph I should provide for periodic negotiation and adjustment of the amount reserved for special termination costs. Occasions for periodic adjustment may include—

        (i) The Government's incremental assignment of funds to the contract;

        (ii) The time when certain performance milestones are accomplished by the contractor; or

        (iii) Other specific time periods agreed upon by the contracting officer and the contractor.

A review of the *DFARS* clause reveals that the clause may be used on incrementally funded contracts when: the contract term is two years or longer and is estimated to require in excess of $25 million of Research, Development, Test, and Evaluation (RDT&E) funds or a total of over $100 million of production investment.

Incrementally funded contracts are those contracts in which funds are incrementally obligated throughout the period of performance. Typically, cost reimbursement RDT&E contracts are incrementally funded and require the use of the Limitation of Funds Clause at *FAR* 52.232-22. This clause requires the contractor to notify the Contracting Officer in writing whenever it has reason to believe the cost it expects to incur in the next 60 days, when added to all costs previously incurred, will exceed 75% of the total amount allotted on the contract (DoD, 2006b, 52.232-22).

Another requirement of the Special Termination Cost Clause (STCC) is that there will be adequate funds available to cover the contingent reserve liability for special termination costs.

In addition, the clause states that the contractor and the contracting officer must agree upon an amount that represents their best estimate of the total special termination costs to which the contractor would be entitled in the event of termination of the contract. These special termination costs are identified within the *DFARS* in the actual Special Termination Costs clause as follows:

252.249-7000 Special Termination Costs.

As prescribed in 249.501-70, use the following clause:

SPECIAL TERMINATION COSTS (DEC 1991)

(a) *Definition.* "Special termination costs," as used in this clause, means only costs in the following categories as defined in Part 31 of the *Federal Acquisition Regulation* (*FAR*)—

   (1) Severance pay, as provided in *FAR* 31.205-6(g);

   (2) Reasonable costs continuing after termination, as provided in *FAR* 31.205-42(b);

   (3) Settlement of expenses, as provided in *FAR* 31.205-42(g);

   (4) Costs of return of field service personnel from sites, as provided in *FAR* 31.205-35 and *FAR* 31.205-46l; and

   (5) Costs in paragraphs (a)(1), (2), (3), and (4) of this clause to which subcontractors may be entitled in the event of termination.

(b) Notwithstanding the Limitation of Cost/Limitation of Funds clause of this contract, the Contractor shall not include in its estimate of costs incurred or to be incurred, any amount for special termination costs to which the Contractor may be entitled in the event this contract is terminated for the convenience of the Government.

(c) The Contractor agrees to perform this contract in such a manner that the Contractor's claim for special termination costs will not exceed $_____. The Government shall have no obligation to pay the Contractor any amount for the special termination costs in excess of this amount.

(d) In the event of termination for the convenience of the Government, this clause shall not be construed as affecting the allowability of special termination costs in any manner other than limiting the maximum amount of the costs payable by the Government.

(e) This clause shall remain in full force and effect until this contract is fully funded. (End of clause)(DoD, 2006a, 252.249-7000)

Thus, the Special Termination Cost Clause limits the amount of special termination (as agreed between the government and the contractor) costs that the Government is liable for in a Termination for Convenience. It should be noted that the STC clause does not apply to the regular termination costs as outlined in *FAR* 31.205-42.

Agency Approval for STCC

As stated in the *DFARS* clause, the use of the STC clause is subject to approval of the agency head. A review of the various agency *FAR* supplements provides some perspective on how this approval is obtained.

The Air Force *FAR* supplement at *AFFARS* 5349.501-70 provides additional and specific policy related to the use of the Special Termination Cost Clause. *AFFARS* 5349.501-70 specifically states the following:

5349.501-70 Special termination costs.

(a) Contracting officers shall refer to Volume 2A, Chapter 1, Section 010213, paragraph C.2 of DoD 7000.14-R, DoD *Financial Management Regulation*, for Congressional notification and additional approval requirements for Special Termination Cost Clauses (STCCs). Because STCCs require special notification to Congress and entail a long approval process over which the Air Force has little control, the contracting officer should allow SAF/AQCK sufficient time to process requests to use *DFARS* 252.249-7000, Special Termination Costs (i.e., not less than 90 days prior to contract award). The request shall include the following:

    (i) A detailed breakdown of applicable cost categories in the clause at *DFARS* 252.249-7000 (a)(1) through (5), which includes the reasons for the anticipated incurrence of the costs in each category;

    (ii) Information on the financial and program need for the clause, including an assessment of the contractor's financial position and the impact of a failure to receive authority to use the clause; and

    (iii) Clear evidence that only costs that arise directly from a termination would be compensated under the clause. Costs that would be incurred by the Government, regardless of whether a termination occurs, shall not be covered by an STCC.

(b) The contracting officer shall obtain SAF/FM approval prior to authorizing any increase in the Government's maximum liability under the clause. (Air Force, 2006, 5349.501-70)

The *AFFARS* is the only agency-level *FAR* guidance that gives more specific instruction on the coordination and review process, as well as on the Congressional notification requirement for the use of STCCs. This guidance also identifies the requirement for referencing the DoD *Financial Management Regulations* (*FMR*) for specific notification and approval requirements.

Statutory Waiver

The second exception to the Termination Liability funding policy is the Statutory Waiver. This exception is explained in the *FMR* as follows:

Statutory Waivers. If a program is exempted by Public Law from the requirement to budget for Termination Liability, the fiscal year increments may be budgeted on a pay-as-you-go basis, providing only sufficient funds to cover the disbursements expected to be made in that fiscal year. When this situation arises, however, the budget exhibits for the program shall clearly indicate the value of the unfunded Termination Liability by year for the current year, budget year, and the outyears covered by the FYDP. (DoD, 2006c)

As can be seen from the above discussion, the regulatory and policy guidance pertaining to the funding of Termination Liability and the use of STCCs is found in two different functionally oriented regulations—the *Financial Management Regulation* (*FMR*) and the *Federal Acquisition Regulation* (*FAR*). This regulatory guidance on budgeting for Contract Termination Liability from two different functional areas of DoD acquisition increases the potential for different interpretations or even misinterpretation of the DoD policy. These differences in policy interpretation are reflected in the practices and procedures used by the various DoD services.

Observations and Findings

The researchers conducted interviews with various DoD program management offices and analyzed samples of DoD contracts related to the management of Termination Liability. Based on these reviews, interviews, and analyses, the research team identified the following observations and findings:

1. Inconsistent Approach

There is an inconsistent approach among the various military and DoD agencies to managing Termination Liability funds on contracts. Although all program offices that were interviewed in this research manage Termination Liability based on the funds obligated on contract, the procedures used for ensuring the obligated funds are adequate and sufficient to cover Termination Liability expense at any point during the contract period of performance varied. Some program offices maintained close coordination with their contractors to monitor and ensure sufficient obligated funds to cover estimated Termination Liability expenses throughout the contract period, while other program offices depended solely on the contractor to monitor the obligated funds to ensure sufficient coverage for Termination Liability. Some program offices conducted periodical "budget drills" to determine if the amount of obligated funds at any given time would be sufficient to cover the estimated Termination Liability at that

point in time. Some program offices used the Contractor Funds Status Report (CFSR) as an aid in monitoring the estimated Termination Liability expenses.

2. Diffused Guidance

The regulatory and policy guidance pertaining to Termination Liability are diffused between the Federal Management Regulation (*FMR*) and the *Federal Acquisition Regulation* (*FAR*). The *FMR* is the main source of financial management policy and guidance used by DoD financial and budget managers, while the *FAR* is the main source for contract management policy and guidance used almost exclusively by DoD contracting officers. These two functionally based regulations lead to differing interpretations of policy, guidance, and procedures related to the management of Termination Liability by the financial-management and contract-management functional areas.

3. Insufficient Databases

There is no DoD-wide, Service-wide, Command-wide, or Center-wide database; yet, one is needed to conduct a proper analysis to determine the total number of contracts that require funding for Termination Liability, the total amount of Termination Liability funding on these contracts, the total number of contracts containing a Special Termination Cost (STC) clause, and the total amount of estimated Termination Liability expenses being managed at the Service levels because of these STC clauses. These databases would provide the data that would be considered a critical part of the business case needed to calculate the extent of the funding being budgeted for Termination Liability expenses.

4. Declining Acceptability of Special Termination Cost Clause

Because of the current acquisition climate of defense acquisition program cost overruns and schedule delays, the increased use of the current Special Termination Cost Clause (STCC) would not be well received by the Congress or the Office of Management and Budget (OMB). Furthermore, program managers are not necessarily receptive to requesting approval of a STCC from their higher headquarters.

Alternative Approaches to Funding Termination Liability

Our research identified the following alternative approaches to managing and funding contract termination Liability.

1. Impose a "Tax" on All Programs Subject to Termination Liability for the Purpose of Establishing an Insurance Fund to Cover Termination Liability.

The advantages of this alternative include the benefit for program managers of not having to commit funds to cover TL, thus allowing better use of funds for program execution. Additionally, since the required Termination Liability funds would be identified prior to any termination, any concerns for possible *Anti-deficiency Act* violations should subside. Finally, for the Military department, significantly fewer dollars would be tied up unproductively for TL and would be available for program execution.

The disadvantages of this option include the fact that those programs not at risk for termination would have to pay this TL tax, thus decreasing their amount of budget for executing

the program. For not-at-risk programs, this tax would make program management more difficult. The dollars associated with this tax would not be available until late in the fiscal year if they were not used to cover a termination; if they were used to cover a termination, the program would lose the money permanently—presenting a lose-lose proposition for the program manager. Finally, another disadvantage would be that at-risk programs would not have the funds required to pay for the tax available for program execution, thus, putting these programs at an increased disadvantage.

Some of the potential questions related to this alternative include the following:

- Who determines the "tax"? Those programs at greatest risk should logically be taxed more than those programs not at risk.

- Who determines the risk of a possible program termination?

- Would the insurance fund provide an attractive target for Congressional rescissions as well as Department reprogrammings?

- When and how would the unused portion of the funds be returned to the programs?

2. Allow Coverage of Termination Liability to be Assumed at the Major Command or PEO Level.

One advantage of this alternative is that program managers could use all of the funds appropriated for their programs for program execution. Additionally, the use of STCCs with the associated Congressional notification would not be required. Another advantage of this approach is that the uncertainty of fund availability (as opposed to the tax approach) would be eliminated. Finally, there would not be a pot of funds to be targeted by Congress or the Department.

The disadvantages of this option include the fact that this approach is similar to the STCC approach—which has not enjoyed strong support from the OMB or the Congress. Additionally, concerns regarding possible *Anti-deficiency Act* violations would likely increase. Finally, another disadvantage would include the fact that paying for a program's termination costs would likely adversely impact other programs.

Some of the potential issues related to this alternative include the following:

- This approach would appear to the OMB and Congress as an attempt to forego budgeting for Termination Liability.

- A program termination late in the fiscal year could be difficult to fund. Above-threshold reprogramming requests are rarely certain or timely.

3. Increase the Use of Special Termination Cost Clauses (STCC)

The advantages of this alternative include the benefit that program managers would be able to use all of the funds appropriated for their programs for program execution. The uncertainty of fund availability (as opposed to in the tax approach) would be eliminated for program managers.

The disadvantages of this option include the fact that Congress and the OMB have already exhibited a lack of enthusiasm for the increased use of STCCs. Additionally, the paperwork involved with STCCs is considered onerous by the programs that have completed it.

Recommendations

Based on the research findings, the following recommendations are provided.

1. Remove ambiguity and improve consistency in the regulations.

The current regulations pertaining to the management of contract termination lend themselves to differing and inconsistent interpretations among the Services and functional areas (program management, financial management, and contract management). If the "liberal" interpretation of current regulations is different from what is desired or is the intent of the agencies, these regulations should be revised to remove any ambiguity and to improve the consistency between the functional areas.

2. Do not impose a tax system to provide funding for potential Termination Liability.

The taxing of program offices for the purpose of generating a pool of funds to use for Termination Liability results in a lose-lose proposition for program offices and may result in more disadvantages than advantages. In addition, the potential issues related to this alternative would require additional research and analysis.

3. Continue to use STCCs for the larger programs with funding or longevity concerns.

For larger, major defense acquisition programs that have a lower probability of termination due to visibility, political ties, or urgency of need, the DoD should continue to support the use of STCCs to allow for greater use of program funds for program execution.

Summary and Conclusion

The purpose of this research was to explore current Department of Defense mechanisms for addressing Contract Termination Liability, review current practices and procedures for funding and managing Termination Liability, and propose alternative approaches to improve the DoD's ability to manage Termination Liability and its effect on defense acquisition programs. This research reviewed the regulatory and policy guidance on Contract Termination Liability. A review of current practices and procedures for funding and managing Termination Liability was conducted based on interviews and document reviews with the Air Force, Navy, and other various DoD agencies. Program management challenges and preliminary observations and findings were then presented. A discussion of alternative approaches to funding Termination Liability was discussed, including the use of Special Termination Cost Clauses (STCC). Finally, recommendations were presented.

The regulations and policies pertaining to the management and funding of Contract Termination Liability are inconsistent and subject to interpretation. Program managers, finance and budget managers, and contracting officers have differing interpretations of the requirement

for funding Termination Liability. Furthermore, the practices and procedures used in defense acquisition program offices reflect this inconsistency.

In addition, the probability that a government contract will be terminated for convenience is very small. Program managers and contractors are aware of the statistics, and their approach to Termination Liability reflects that knowledge. The normal procedure for handling the potential liability associated with a contract terminated for convenience is to "budget" for the liability. Then, in coordination with the contractor, the required amount of funding is tracked on a regular basis. In this case, budgeting for Termination Liability does not mean obligating funds specifically for that purpose.

Additionally, program managers are not in favor of a "tax" that would negate the requirement to budget for TL. For the most part, they are satisfied with the status quo because the procedure they currently use to handle TL allows them to keep all of the funding appropriated for their program. A tax would deprive them of funds they currently have at their disposal. In fact, a program that has funding problems could be put in jeopardy by having to relinquish funding to pay for a tax. Program managers feel as though the statistics support their current approach.

Furthermore, if all programs were taxed, there is a general concern that the pooled funds would likely be lost for good—either the military Departments (or DoD) would use them to solve other problems if they were not required to cover a liability, or Congress would look upon the funds that had been set aside as a "slush fund" and be tempted to use them elsewhere.

Also, support for increased use of STCCs is not evident, either at the program level or the OMB or Congressional level. Congress has expressed its concern regarding STCCs through report language. OMB correspondence has indicated that support for more than one STCC per service is unlikely. However, it should be noted that those programs that have significant funding problems and/or are concerned about the possibilities of termination do support additional use of STCCs. In fact, these programs would prefer to have a STCC that covers more cost elements than the standard STCC.

Finally, this research recommended that the Department of Defense: remove the ambiguity and improve the consistency in the regulations pertaining to the management of Termination Liability, not impose a tax system to provide funding for potential Termination Liability, and continue to use STCCs for the larger programs with funding or longevity concerns.

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Panel 14 - Capabilities Assessment & Privatization of Defense Acquisition

Thursday, May 17, 2007	**Panel 14 - Capabilities Assessment & Privatization of Defense Acquisition**

11:15 a.m. – 12:45 p.m.	**Chair:**
	
	G. Frederick Thompson, Professor of Public Management and Policy, Atkinson Graduate School of Management, Willamette University
	
	Papers:
	
	Improving National Defense Acquisition and Resource Management through Enterprise Organization, Capabilities Assessment, Radical Reengineering, Capital and Longer-term Budgeting and Privatization/Marketization
	
	    Lawrence R. Jones and **Jerry L. McCaffery**, Naval Postgraduate School
	
	Budget Uncertainty and Business Management Reform in the Department of Defense: Some Consideration for Acquisition Management
	
	    Philip J. Candreva and **Douglas A. Brook**, Naval Postgraduate School

Chair: G. Frederick Thompson, Professor of Public Management and Policy, Atkinson Graduate School of Management, Willamette University

Improving National Defense Acquisition and Resource Management through Enterprise Organization, Capabilities Assessment, Radical Reengineering, Capital and Longer-term Budgeting and Privatization/Marketization

Presenter: Lawrence R. Jones, PhD, serves as Admiral George F. A. Wagner Professor of Public Management in the Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA. Professor Jones teaches and conducts research on a variety of government financial and management reform issues. He has authored more than one hundred journal articles and book chapters on topics including national defense budgeting and policy, management and budget control, public financial management, and international government reform. Dr. Jones has published fifteen books including *Mission Financing to Realign National Defense* (1992), *Reinventing the Pentagon* (1994), *Public Management: Institutional Renewal for the 21st Century* (1999), *Budgeting and Financial Management in the Federal Government* (2001), *Strategy for Public Management Reform* (2004), and *Budgeting and Financial Management for National Defense* (2004).

Presenter: Jerry McCaffery, PhD is a Professor of Public Budgeting in the Graduate School of Business and Public Policy at the Naval Postgraduate School where he teaches courses focused on defense budgeting and financial management. He has taught at Indiana University and the University of Georgia. His current research interests include defense transformation and the PPBE system and their impact on DoD acquisition and resource allocation. He and Professor Jones are the authors of *Budgeting and Financial Management for National Defense* (2004).

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Abstract:

Our guiding assumption in organization of our research and this report is that to understand the defense acquisition process and reform arguments, it is necessary to know something about the organizational and managerial context in which such reform must take

place. Consequently, this report for the 2007 NPS Acquisition Symposium is organized into four parts: (i) an analysis of the Enterprise organization and management initiative now underway in Department of Defense (DoD), demonstrating (ii) how it encompasses the new approach to defense capabilities thinking, planning and management as a preamble to our argument for acquisition system and process reform. Along the pathway to presentation of our acquisition reform proposals, we show (iii) the role of better business practices and information technology in adding value to DoD acquisition and resource management in terms of improved organization strategy based on lessons from economics in the private sector in evolving from bureaucracy to hyperarchy and netcentric organization. It this section, we draw lessons from the manner in which businesses operate in the new global economy and how the development of new information technology should enable managerial reform. This analysis supports the types of change we recommend later in the report in a way that adds value to DoD acquisition and resource management. We advance our analysis in part by applying lessons from economic, information and value-chain theory and practice, illustrating the utility of this approach using the examples of Toyota Motor corporation and the DoD Global Information Grid (GIG); by employing these examples, we demonstrate both possibilities and obstacles to be overcome in reorganizing the DoD and its acquisition and resource management processes to better meet market demand and to respond to changes in the threat environment. Part of this argument includes assessment of the application of new technology, particularly IT, and the principle of netcentricity and hyperarchy in DoD reorganization and acquisition/resource management reform. We assert the necessity for understanding something about the new economics of organizations and a critique of bureaucratic organization as critical intellectual components of support for our proposed reforms. Finally, (iv) we advance two approaches to reform in terms of magnitude of change in DoD acquisition, procurement and resource management: (a) an argument for marginal adjustment based on our view of the need for implementation of longer-term capital and performance-oriented budgeting in combination with radical DoD business process reengineering, consistent with the principles, methods and goals of enterprise management, and (b) a much more radical conversion of the DoD to an approach that we term "marketization and privatization" of defense acquisition systems and resource-management processes. We note that these options are not mutually exclusive, as both are needed.

Preface

Problem: If a cop in Anytown, USA, pulls over a suspect, [ideally] he checks the person's ID remotely from the squad car. He's linked to databases filled with Who's Who in the world of crime, killing and mayhem. In Iraq, there is nothing like that. When our troops and the Iraqi army enter a town, village or street, what they know about the local bad guys is pretty much in their heads, at best. Solution: Give our troops what [some of] our cops have. The Pentagon knows this. For reasons you can imagine, it hasn't happened... This is a story of can-do in a no-can-do world, a story of how a Marine officer in Iraq, a small network-design company in California, a nonprofit troop-support group, a blogger and other undeterrable folk designed a handheld insurgent-identification device, built it, shipped it and deployed it in Anbar province. They did this in 30 days, from Dec. 15 to Jan. 15. Compared to standard operating procedure for Iraq, this is a nanosecond... Before fastening our seatbelts, let's check the status quo. As a high Defense Department official told the *Journal*'s editorial page, "***We're trying to fight a major war with peacetime procurement rules.***" The department knows this is awful. Indeed, a program exists, the Automated Biometric Identification System: retina scans, facial matching and the like. The reality: This war is in year four, and the troops don't have it. Beyond Baghdad, the US role has become less about killing insurgents than arresting the worst and isolating them from the population. Obviously it would help to have an electronic database of who the bad guys are,

their friends, where they live, tribal affiliation—in short, the insurgency's networks... The Marine and Army officers who patrol Iraq's dangerous places know they need an identification system similar to cops back home. The troops now write down suspects' names and addresses. Some, like Marine Maj. Owen West in Anbar, have created their own spreadsheets and PowerPoint programs, or use digital cameras to input the details of suspected insurgents. But no Iraq-wide software architecture exists... On the night of Jan. 20, Maj. West, his Marine squad and the "jundi" (Iraq army soldiers) took the MV 100 and laptop on patrol. Their term of endearment for the insurgents is "snakes." So of course the MV 100 became the Snake Eater. The next day Maj. West e-mailed the US team digital photos of Iraqi soldiers fingerprinting suspects with the Snake Eater. "It's one night old and the town is abuzz," he said. "I think we have a chance to tip this city over now." A rumor quickly spread that the Iraqi army was implanting GPS chips in insurgents' thumbs... Over the past 10 days, Maj. West has had chance encounters with two Marine superiors—Maj. Gen. Richard Zilmer, who commands the 30,000 joint forces in Anbar, and Brig. Gen. Robert Neller, deputy commanding general of operations in Iraq. He showed them the mobile ID database device... I asked Gen. Neller by e-mail on Tuesday what the status of these technologies is now. He replied that they're receiving advanced biometric equipment, "like the device being employed by Maj. West." He said "in the near future" they will begin to network such devices to share databases more broadly. Bottom line: "The requirement for networking our biometric capability is a priority of this organization." As he departs, Maj. West reflected on winning at street level: "We're fixated on the enemy, but the enemy is fixated on the people. They know which families are apostates, which houses are safe for the night, which boys are vulnerable to corruption or kidnapping. The enemy's population collection effort far outstrips ours. The Snake Eater will change that, and fast." You have to believe he's got this right. *It will only happen, though, if someone above his pay grade blows away the killing habits of peacetime procurement.* [comments in brackets, italics and bold added by Jones and McCaffery.] (Henninger, 2007, p. A14).

Introduction

In previous research sponsored under the Naval Postgraduate School (NPS) acquisition research program, we have argued (2005) that there are mismatches and discontinuities between the acquisition decision process and the Planning, Programming, Budgeting and Execution System (PPBES). We identified a number of problems associated with the misalignment of these two Department of Defense (DoD) resource-decision systems. To reduce misalignment, we recommended significant business process reengineering of both systems. We are pleased to observe that some of what we recommended was implemented by the former Under Secretary of Defense for Acquisition, Technology and Logistics (USD AT&L) Kenneth J. Krieg and the military departments and services (MILDEPS). However, in May 2006, the Under Secretary stated that while some successful reengineering had been done, more was needed. In December 2006, the USD AT&L noted that he was planning to do more of this within his own staff and within the decision processes he controls.

With respect to further changes to bring better alignment between the acquisition decision process and PPBES, we now conclude that not much more is likely to occur soon despite the need for resolution of the many mismatches between the two processes. The initiative to further reform PPBES has disappeared with the departure of former Secretary of Defense Donald Rumsfeld as champion of administrative transformation, and the absence of funding to finance it due to the continued demands placed on the DoD to finance OIF and the Long War. Without additional PPBES and budget reform, we do not believe it is possible to

improve the fit between resource allocation and acquisition decision processes in the near term to any significant degree.

In 2006, we presented our research at the NPS Acquisition Symposium that argued for implementation of capital budgeting in the DoD and across the federal government, with emphasis on mirroring to some extent how it is done in the private sector. We also explained how capital budgeting could be implemented within the DoD without changing the congressional decision process, and explained some of the issues to be resolved to do so. We are pleased to observe that the office of the USD AT&L has been implementing some of our recommendations on capital budgeting.

For the 2006-2007 acquisition funding cycle, we have concentrated on four areas that we report upon in this paper for the 2007 NPS Acquisition Symposium. Our guiding assumption in organization of our research and this report is that to understand defense acquisition process reform, it is necessary to know something about the organizational and managerial context into which such reform must take place. Accordingly, we provide analysis of the Enterprise organization and management initiative now underway in the DoD, and show how it encompasses the new approach to defense capabilities thinking, planning and management as a preamble to our argument for acquisition system and process reform. Along the pathway to presentation of our acquisition reform proposals, we show how the development of new information technology should enable managerial reform of the type we recommend in a way that adds value to DoD acquisition and resource management. We advance our analysis in part using the example of the DoD Global Information Grid (GIG) to demonstrate both possibilities and obstacles to be overcome in the application of IT and the principles of netcentricity. We also assert the necessity for understanding something about the new economics of organizations as a critical intellectual component of support for the arguments we make for defense acquisition and resource-management reform.

The first part of this report provides an assessment of the efforts currently in progress to apply enterprise management in the Navy and the DoD. In this report, for purposes of description and analysis of the Enterprise organizational framework and structure under which change has been partially implemented in the DoD, we use the example of the Navy and the Naval NETWAR FORCENET Enterprise or NNFE.

In the second part of this report, we examine the introduction of capabilities-based thinking, planning and decision-making into the enterprise organization and management systems, and into the analysis required to support defense acquisition planning and decision-making. We identify and analyze some of the issues faced in application of capabilities-based planning and resourcing, especially those relating to definition of capabilities and deriving methods to crosswalk from (a) traditional program-based proposal and acquisition management to (b) capabilities-based proposal and management. As we indicate, implementation of capabilities-based planning and management in the defense acquisition process changes and adds to the tasks to be performed and the information needed for decision and execution by the Office of the Secretary of Defense (OSD)—particularly the US AT&L and the Secretary (SECDEF), the Joint Chiefs of Staff (JCS) and the military departments and services (MILDEPS): e.g., data needed to build the POM, the SECDEF budget proposal and to perform medium-term capital asset acquisition planning and decision-making at various levels within the DoD.

The third part of this report explains the role of new technology, including information technology (IT), in a new approach to defense acquisition and budgeting. We argue here that IT

provides the basis and potential for almost all managerial and systems reform in the DoD, basing some of our conclusions on evidence from theory and private-sector practice. More broadly, to understand how defense acquisition can and should be done incorporating new technology, we explain the vital role of IT in moving from bureaucracy to hyperarchy and netcentric organization to add value in reform of defense acquisition and resource management, i.e., to enable the types of change we advocate subsequently in the report. This part of the report also advances the relevance of the new economics of organization as a component part of the theoretical and practical underpinnings for reform of defense acquisition and resource management. In essence, we argue the necessity for relying on markets and the private sector in moving from bureaucracy to hyperarchy and netcentric organization.

The fourth and final part of the report outlines and articulates our proposals for fundamental reform of the entire defense acquisition management system and decision process, based on and integrated with the DoD Enterprise organization and management initiative and capabilities-based analysis, decision-making and implementation. We have developed two approaches to reform. The first is a marginal adjustment set of changes to the current system to make it more efficient and productive (i.e., to reduce cycle-time, reduce costs and improve quality per investment dollar) through business process reengineering, enterprise management and improved use of information technology (IT).

The second proposal is for a much more comprehensive and radical reform of how the DoD acquires and procures weapons platforms and systems. The comprehensive reform proposal we refer to as, "privatization and marketization of DoD acquisition." In essence, this proposal argues that to operate defense acquisition more like a business, using better business methods and processes, it is necessary, literally, to make DoD acquisition a business: i.e., to move much of the present DoD process out of the government and to firms in the private sector. In addition, we argue that in facing the make-or-buy decision as all corporate entities must, increased and better acquisition and procurement of commercial off-the-shelf (COTS) weapons, systems and equipment from a worldwide market will get the US taxpayer greater "bang for the buck" in acquiring weaponry for defense and will better and more quickly meet warfighter needs.

We argue that the key advantage of the more comprehensive reform approach is to take full advantage of the competitive dynamics of an international defense capital asset market in the same way that large firms in the private sector operate presently—rather than relying on the system and process the DoD uses now which is, in essence, a gigantic, disconnected and inherently ineffective government bureaucracy that resembles in form a Cold War-era, Soviet-style, long-range planning hierarchy in which *the process has become the product*. We argue for a transition to a system in which the product is the focus of decision effort, and we outline how such a system would operate and some of the most important issues to be resolved in privatizing DoD weapons systems acquisition.

> The complex nature and consequent length of this report made it impossible to reproduce the entirety in these *Proceedings*. To read the rest of this paper in full text, please see www.acquisitionresearch.org.

Budget Uncertainty and Business Manangement Reform in the Department of Defense: Some Considerations for Acquisition Management

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Author: Douglas A. Brook, Ph.D., is Professor of Public Policy and Director of the Center for Defense Management Reform in the Graduate School of Business and Public Policy at the Naval Postgraduate School. In the administration of President George Herbert Walker Bush, Dr. Brook served as Assistant Secretary of the Army (Financial Management) and as Acting Director of the U. S. Office of Personnel Management. Dr. Brook holds a Ph.D. in Public Policy from George Mason University, and MPA and BA degrees from the University of Michigan.

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Abstract

Business management reform efforts have been part of the US Defense Department agenda for decades. Current reform efforts have explicitly established the goal of generating, harvesting, and reinvesting savings from business management reform to buy more capital items; that is, they have focused on a measurable reallocation from operating and support costs to investment within a given budget top-line. While this would seem to be good news for the acquisition community, recent increases in the defense top-line, largely related to the war on terrorism, have not necessarily resulted in greater allocations for acquisition. An examination of the factors affecting the top-line suggests that near-term budget uncertainty is likely. An examination of current and past defense management reforms suggests that efficiency-seeking business management reforms are not likely to generate sufficient resources to cover a budget decline or finance significant capital reinvestment. Instead, management reform, including on-going reform of acquisition management, should be sustained for reasons of stewardship and accountability.

Keywords: Defense management, defense budgets, management reform

Acknowledgements

Introduction

After six years of increasing budgets and an active defense management reform agenda in the G.W. Bush Administration, it now appears that defense budgets may be headed for a more uncertain near-term future, and the future role of management reform initiatives may be equally uncertain. Despite significant increases in defense spending, resource allocation decisions are favoring operating expenses over capital investments. External pressures from the budget deficit, rising costs for entitlement programs, pressure from other discretionary programs in the federal budget and public opinion regarding defense activities suggest that total resources allocated for defense will be constrained in the foreseeable future. Internal pressures from rising costs for manpower, health care, operations and maintenance are constraining discretionary spending inside the defense budget—even as acquisition costs are also increasing. The Department of Defense (DoD) and the individual service components have been looking toward major management reform initiatives as a means to save and reinvest resources within current budget projections. What are the implications of this budgetary and management environment for acquisition?

Why the Near-term DoD Budget May Be Uncertain

When one asks whether the DoD budget top-line will rise or fall, there are both historical patterns which should be considered as well as internal and external factors that affect those patterns.

Figure 1 displays three measures of the defense top-line over the period 1940-2011. In absolute terms, since WWII, defense outlays appear as a cyclical pattern with a lower limit of about $350 billion and an upper limit of about $550 billion in FY2006 dollars. The cycles are fairly consistent with a wavelength ranging from 15 to 21 years. Fiscal Year 2007 is 18 years since the last peak in 1989, suggesting that *if the long-term pattern repeats*, defense will face declining absolute top-lines beginning within the next few years and continuing for 7-10 years.

Defense Spending 1940-2011
Source: Historical Tables, Budget of the United States, 2007
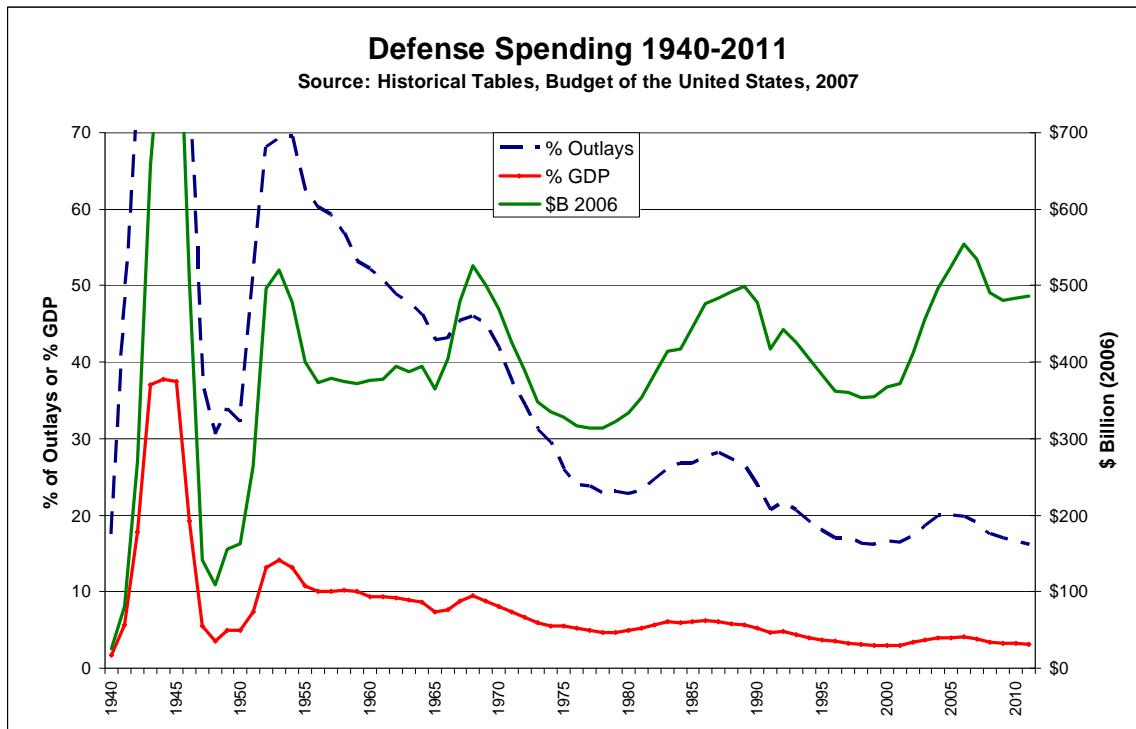
Figure 1. Defense Top-line 1940-2011: Various Measures
(OMB, 2007)

In relative terms, since WWII, defense spending as a percentage of GDP has fallen rather steadily from a peak of 14.2 percent in 1952 to a low of 3 percent in 1999-2000. In 2006, defense spending stood at about 4.1 percent of GDP. Similarly, defense spending as a percentage of federal outlays has also fallen significantly, from a peak of 69.5 percent in 1954 to a low of 16.1 percent in 1999. In 2006, defense was 19.8 percent of federal outlays. Today, approximately 1/5 of federal government spending is for national defense, and 4/5 are for other functions of government; in the 1950s, 2/3 of government spending was defense. *Should the long-term trends continue*, defense can expect declining relative top-lines.

Simply identifying the trend of the last 50 years does not mean that trend will apply to the next 3-5 years. We do not have the knowledge to make a point prediction. More than a long-term trend is needed, and there are other factors that may affect the top-line—those both external and internal to the department. Apart from the obvious effects of the war, certain external factors are associated with federal fiscal policy and political dynamics.

External Fiscal Factors

Deficits. As of 2006, the US has experienced four consecutive years of budget deficits following four consecutive years of budget surpluses. The Bush Administration's position is that it will eliminate such annual deficits by 2012. When an administration or congress wishes to reduce a deficit, generally it requires a combination of increasing revenues and decreasing outlays. If defense maintains even a steady proportion of federal spending during an overall

decline, it will lose top-line.[2] But the correlation between defense spending and deficits may be even more closely connected.

Defense Spending vs Budget Deficit (Surplus), 1979-2006
in constant 2006 dollars
Correlation coefficient = -0.64, significant at 0.001
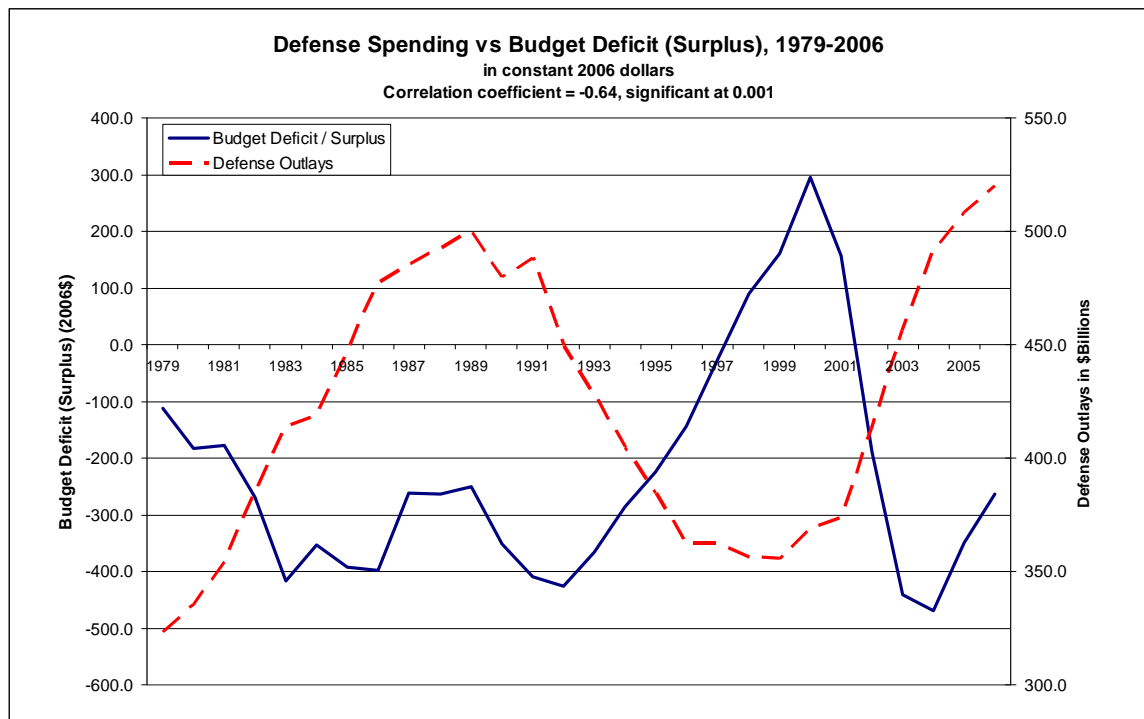
Figure 2. Defense Spending and Deficits, 1979-2006
(OMB, 2007)

Figure 2 plots budget deficits against defense spending from 1979 to 2006. It is readily apparent that as defense spending rose, deficits increased; as spending on defense fell, deficits fell to the point of achieving surpluses. Defense spending does not necessarily cause deficits; rather, each could be affected by a third factor such as an unstable international situation. However, the apparent relationship suggests near-term uncertainty for the defense budget as deficit-reduction policies take hold.

Mandatory Programs. Defense spending has fallen from 2/5 of federal spending to 1/5 in the past 40 years, supplanted by mandatory spending; see Figure 4. From 1966 to 2006, interest on the debt and "all other spending" accounted for roughly the same proportion of federal spending—about 41 percent. The remaining 59 percent was largely defense spending in 1966; at that time, defense spending was three times more than Social Security spending. In the intervening 40 years, the proportion of federal spending on defense was reduced more than 50 percent while Social Security rose by 40 percent. Health programs, new in 1966, represent nearly as much as defense in 2006.[3]

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[2] Of course, if growth is kept below the rate of inflation, there could be deficit reduction with a nominal increase in the top-line.

[3] If one allocates the health-care related programs from defense and "all other spending" and adds them to the Medicare & Medicaid wedge, the total health care portion grows to about 25 percent while defense falls to about 19 percent. See table 16.1 of the Historical Tables that accompany the federal budget for Fiscal Year 2008.
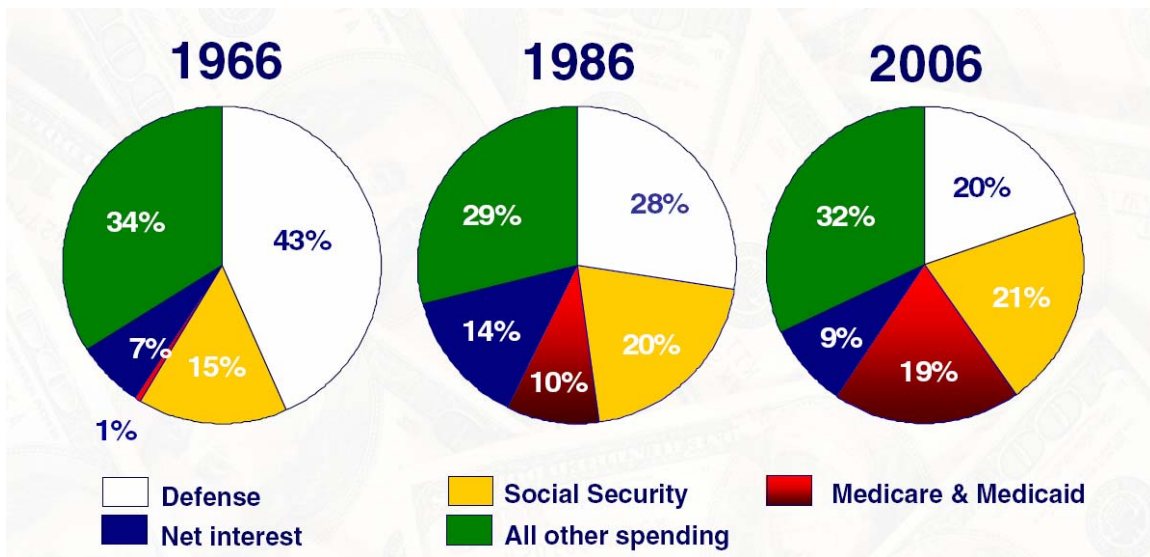
Figure 3. Components of Federal Spending
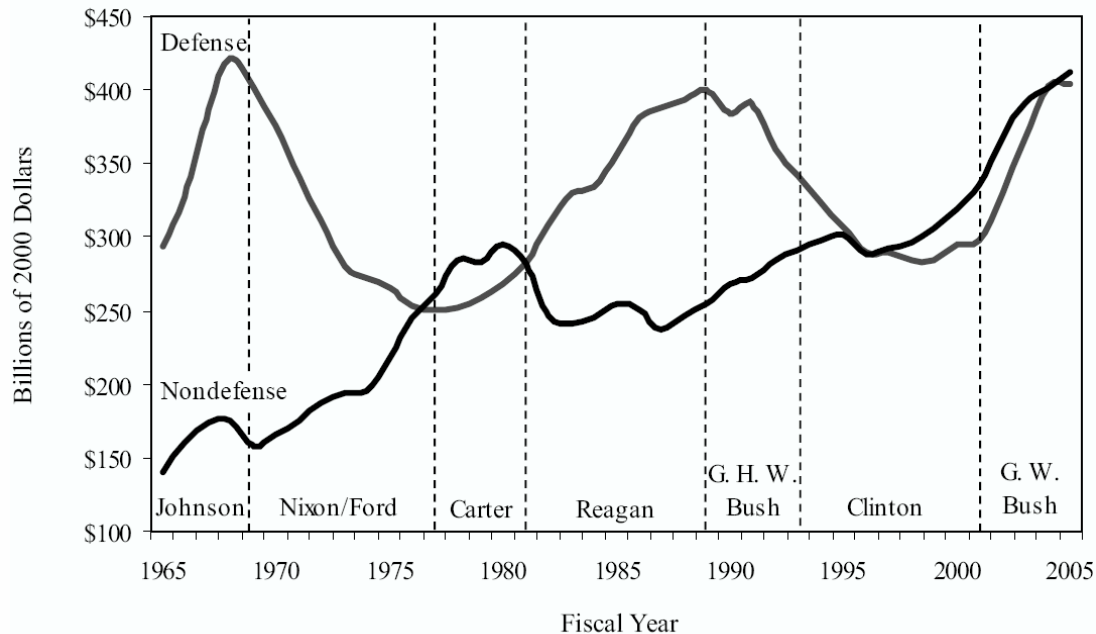(OMB, 2007)

The Congressional Budget Office estimates that this shift will continue. It estimates that in 2016, the mandatory programs will cost $1,274 billion more than in 2006—rising to a total of $2,793 billion (CBO, 2006). That is more than all the projected federal outlays, mandatory and discretionary spending in 2007. The CBO projects that in the period from 2008-2017, discretionary budget authority will increase at 2.0 percent per annum, relative to GDP growth of 4.5 percent, while mandatory spending will grow at 5.9 percent (CBO, 2007).

Non-defense Discretionary Spending. Defense top-lines not only feel pressure from growing entitlement programs, but may also face pressure from other discretionary programs. From 1985 to 2006, total discretionary outlays as a percentage of GDP fell from 10.0 percent to 7.8 percent. Of those 2.2 percentage points, defense spending accounted for 2.1 and other discretionary spending accounted for 0.1 (CBO, 2007). Nearly the entire reduction in discretionary spending was absorbed by defense. The last few years of that history tell a different story, however. From 2001 to 2006, total discretionary outlays as a percentage of GDP rose from 6.3 percent to 7.8 percent. Of that 1.5 percentage point increase, defense accounted for 1.0 point and non-defense accounted for 0.5 (CBO, 2007). Figure 4 displays a 40-year trend in discretionary spending separating defense from non-defense spending. We see again the cyclical nature of defense spending with a counter-cyclical, but steadily upward trend in non-defense spending.

Figure 4. Defense & Non-defense Spending by Administration
(OMB, 2007)

External Political Factors

How responsive are Washington decision-makers to the demands of the public? The evidence strongly suggests that if the general public believes defense spending is too high, defense spending declines and vice-versa. Studies conducted at the end of the Cold War demonstrated empirically that the desires of the public are reflected in future spending decisions (Hartley & Russett, 1992; Higgs & Kilduff, 1993).

Updating that research, Figure 5 displays the direction and strength of public opinion about defense spending with subsequent changes in that spending. Change in defense spending correlates strongly with the direction and strength of public opinion. When public opinion favors increased defense spending, spending has tended to go up the following year; when the public favors a decrease, spending tends to drop the following year. The intensity of public opinion also forecasts the significance of the gain or drop. In combination with the data in Figure 1, one might conclude that the public has a "comfort zone" of appropriate defense spending that ranges between $350 billion and $550 billion (FY2006 dollars). Yet, defense spending for FY08 is projected to be $593 billion (FY2006 dollars).
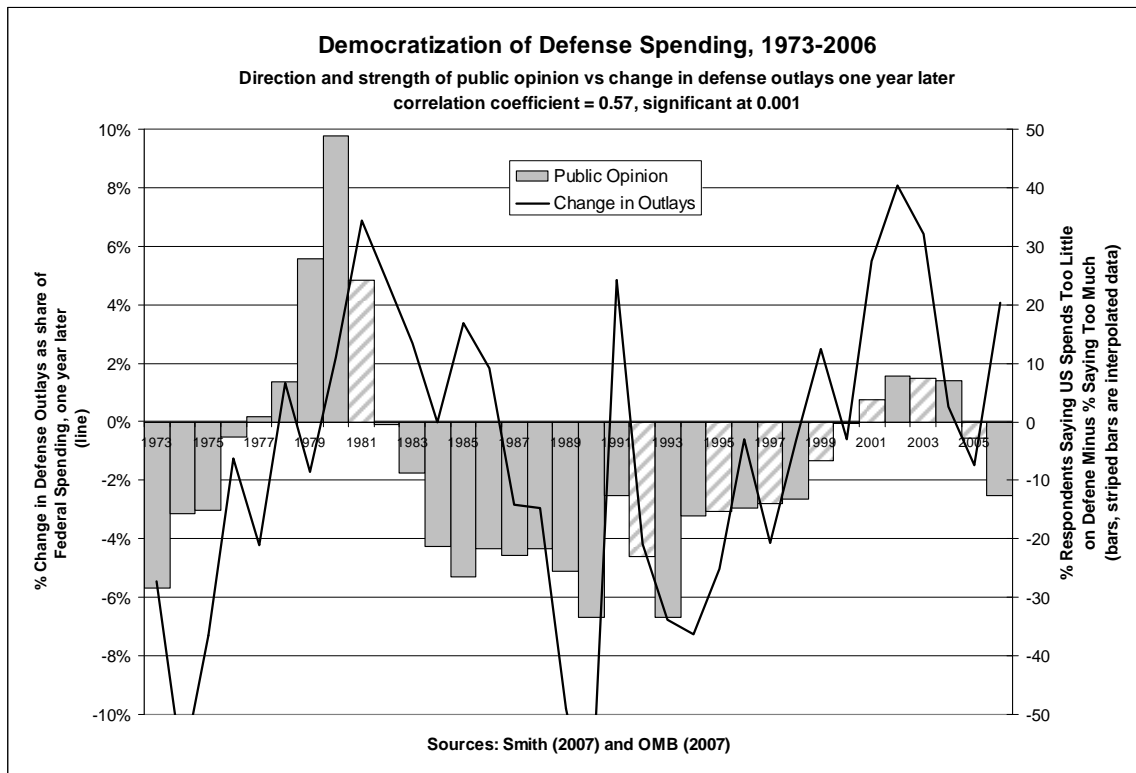
Figure 5. Public Opinion and Defense Spending
(Authors, derived from Smith, 2007; OMB, 2007)

What does the public currently believe about defense spending? The polling data used in Figure 5 indicates that in 2006, 39.4 percent of Americans favored reduced defense spending, contrasted with 26.8 percent who favored an increase (Smith, 2007). The Program on International Policy Attitudes (PIPA) at the University of Maryland researches American attitudes regarding international and foreign policy issues. An extensive survey in 2005 asked a representative sample of Americans to reallocate a hypothetical $1000 in income taxes across federal programs in the proportion they believed was most appropriate. Before the reallocation, they were shown the actual 2006 budget. These survey respondents would have cut the DoD baseline budget by 31 percent and war supplemental appropriations by 35 percent. They would have reallocated most of those resources toward reducing the deficit and improving education. They favored increases in international affairs programs and would have reallocated defense spending away from strategic and heavy capacity (e.g, nuclear weapons, bomber aircraft and capital ships) toward manpower, communication, intelligence and special operations capabilities (PIPA, 2005).

To summarize, there has been fiscal pressure on the defense top-line from growth in mandatory spending accounts and non-defense discretionary accounts. We are again at a time when deficits are a point of concern. Politically, the current Administration faces increased congressional opposition to military policies; public support of defense spending is waning. Time will tell how that manifests in spending decisions. External factors are vital when considering current defense management reform, but internal factors may be more important.

Internal Factors

Internal factors affecting defense spending are those defense leaders are more able to directly control. They include budgeting and spending for acquisition, personnel, and operation and maintenance. The policy of budgeting for the war separately also confounds analysis of defense spending. Before looking at specific factors, let us take a broad view. From the low point of the 1990s "procurement holiday" to today, the DoN's budget has increased 46 percent in real terms, but the size of the fleet fell from 354 battleforce ships to 280; aircraft inventory fell from 2,559 to 2,330; and the number of personnel (uniformed and civilian) fell from 929,358 to 829,531 (Navy, 2007b). While spending increased by half, the naval forces are 15 percent smaller. The last time defense experienced twelve continuous years of budget growth was 1979-1990 during which time the fleet grew from 530 to 587 ships.

To sustain the current goal of a 313-ship Navy, there needs to be sufficient shipbuilding budget authority to consistently build an average of eleven ships a year. Since 1998, Navy 5-year budgets have planned to build eight ships per year but have succeeded in building only six ships per year. To get to twelve will require nearly doubling the annual shipbuilding budget, currently at $11 billion (CRS, 2006b). Can management reform efforts generate $10 billion from the other accounts?

Acquisition Costs

The Department's appetite for major acquisition programs and the cost performance of those programs continue to be important issues. The Joint Strike Fighter, F-22A, the Army Future Combat System, the Air Force's Transformational Satellite System, the Navy's DD-1000 and Virginia-class submarine programs have all experienced significant cost growth, quantity reductions or schedule slips (CRS, 2005). In early 2007, the Navy acquisition executive issued a stop-work order for the relatively affordable Littoral Combat ship when the first ship in the class experienced costs 50 percent over budget. Thus, one comes to the difficult realization that just as other internal and external factors are putting pressure on the fiscal resources available for recapitalization, acquisition itself is a source of fiscal stress.

Personnel Costs

Pay and benefits for personnel have increased in recent years. At the same time, accrual accounting changes have illuminated some costs (such as the accrued costs of retiree heath care) which have always been there, but weren't explicitly recognized. The activation of tens of thousands of reservists and guardsmen for the Iraq war resulted in higher pay and increased long-term liabilities because their benefits packages have been expanded. Figure 7 plots Department of the Navy spending from 1997-2008 on pay, allowances and family housing against the total number of active and reserve Navy and Marines. In constant dollars, the cost per troop has risen 47 percent. In an effort to hold outlays constant, the policy has been to reduce the size of the force.

Personnel Spending vs # Uniformed Members
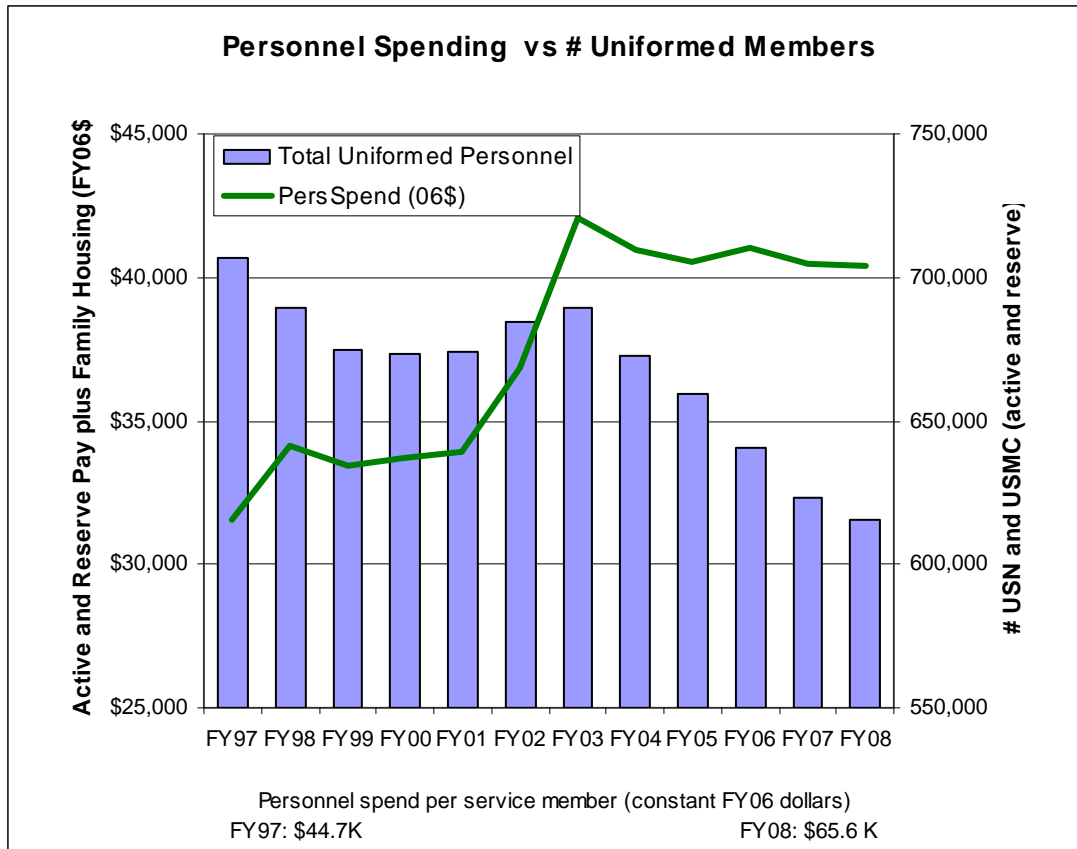
Figure 7. Rising Personnel Costs, Measures
(Navy, 2007)

Operations and Maintenance Costs

Looking back, O&M spending in the Department of the Navy since 1997 (including the significant Marine Corps participation in GWOT) has remained a steady 32 percent of DoN spending, but that is at a time when the force structure has decreased 15 percent (Navy, 2007b). Looking forward, the war's toll on equipment will drive up O&M requirements for the next few years, particularly in depot maintenance (GAO, 2006). However, that is not readily apparent in the budget. The FY2008/2009 defense budget, like all defense budgets since 9/11, was tallied and submitted separately from the wartime supplemental budget. Because of that practice, the baseline budget for Marine Corps depot maintenance shows a decrease from $372 million in 2006 to $71 million in 2008 (Navy, 2007a). Separately, the Marine Corps requested an FY2008 supplemental appropriation of $490.6 million for this account. If one has the wherewithal to marry the two, they will see that depot maintenance is actually projected to increase from $372 million to $562 million, not decrease. Program and budget analysts, in an attempt to separate a "peacetime" budget from the cost of war, now produce twice the number of documents (leading to twice the legislation and twice the number of accounts to manage)— none of which individually accurately portrays the true level of activity.

Other supplemental appropriation issues

The wartime supplemental appropriations confound analysis of defense spending further. When the Navy submitted its FY2008 budget, it announced cuts in the acquisition of

aircraft (Castelli, 2007) but replaced a large number of those aircraft in the supplemental requests. For example, nine H-1 helicopters were cut from the base, but requested in the supplemental; eight H-60 helicopters were cut from the base, but nine were requested in the supplemental; four V-22 tilt-rotor aircraft were cut from the base, and three were requested in the supplemental (despite the fact the V-22 has not been used in the war) (Navy, 2007). Theses practices cause distortions in baseline budgets that may negatively affect future DoD budgets after the use of supplemental appropriations ceases unless some type of "recapture" takes place.

Summary

Will the defense top-line rise or fall over the next few years? Long-term historical trends suggest that by all measures (%GDP, %Outlays, constant dollars), defense spending is likely to fall. If one takes into consideration factors in the near-term, we see evidence of downward pressure. External factors such as growing entitlement programs and growing discretionary programs restrict the room for growth in the defense budget, particularly during periods when there is political pressure to reduce deficits. In addition, the newly-elected Democratic leadership in Congress and the direction and strength of public opinion question increased defense spending. Internal factors push for a higher top-line but include significant inflationary effects, so top-line increases have bought less force structure (but not necessarily less capability). Supplemental appropriations for the war are likely to continue and provide an opportunity for the defense department to seek relief from budget pressures. The Bush Administration requested a significant defense budget increase in FY2008, 11 percent more than in FY2007; but the DoD is already exhibiting signs of fiscal stress. No one can say for certain what will happen in the future, but it appears the defense budget is under both increased stress as well as increased scrutiny.

Defense Business Management Reform

How does this budget situation relate to business management reform within the DoD? A review of the recent history of defense business management reform and an examination of the current management reform agenda suggest some implications for both budgeting and managing in a time of uncertain budgets.

Recent History of Defense Business Management Reform

The George W. Bush Administration also came to office with a management focus. The President's Management Agenda (PMA) addresses five areas targeted for management reform throughout the federal government: human capital, improved financial management, competitive sourcing, electronic government, and budget and performance integration (Rumsfeld, 2003).

In the DoD, an initial management objective was to "increase effectiveness through increased accountability and efficiency" (Rumsfeld, 2002), with emphasis on cost reduction, improving quality, reducing redundancies, and adopting best business practices. Secretary Rumsfeld emphasized the creation and use of metrics to quantify performance improvements, and he sought to focus the Department's resources on core functions (Francis & Walther, 2006). To improve its efficiency, the DoD is tackling several significant challenges: cost reduction, organizational realignment and cultural issues (Walker, 2004).

The DoD has identified six major, strategic, high-leverage initiatives called Business Enterprise Priorities (BEPs). These BEPs include achieving better visibility into personnel,

acquisitions, materiel, finances, common supplier engagement and real property accountability (DoD, 2006a). Oversight of defense business transformation is conducted by the Defense Business Board, an advisory panel consisting of private-sector executives chartered to provide, "independent advice and recommendations on effective strategies for the implementation of best business practices of interest to the Department of Defense" (DoD, 2007).The Department's Business Management Modernization Program (BMMP) and Defense Business Transformation Agency (DBTA) were created to institutionalize parts of the DoD change program. DBTA's strategic objectives include improving financial stewardship, enabling rapid access to information, and reducing the costs of defense business operations (Pair, 2007). DBTA has established seven directorates to manage its reform agenda—including the Defense Business Systems Acquisition Executive.

The Army, Navy and Air Force have developed service-specific management reform agendas, as well. Lean Six Sigma is the Army's tool of choice to drive across-the-board elimination of unnecessary or wasteful processes, the reduction of process variability, and the improvement of quality (Army, 2006). The Air Force intends to create new processes through its Smart Ops 21 program, which encompasses the tools of Lean, Six Sigma and Theory of Constraints (Lopez, 2005). The Navy's Sea Enterprise initiative aims to reduce costs in order to provide internally generated resources for reinvestment and recapitalization (Clark, 2002).   Sea Enterprise has identified three imperatives: change the culture, improve processes and structures, and harvest savings.[4] The Navy is also undertaking a challenging enterprise realignment to create a more matrixed organization and to create a culture of enterprise-wide thinking.

The current management reform agendas have a defining distinction: they focus on generating internal savings through effective cost management to support investment and recapitalization for the operating forces. This vision has been much more explicit than those of past reform efforts. It provides a measurable objective, and it aligns with the core values and mission of the organization.

There are practical issues associated with this objective, of course, such as how to re-allocate operating funds to investment accounts effectively in an execution year, how to track and apply savings within the current accounting systems, and how to distinguish between "real" savings and future cost avoidance. Even if these obstacles can be overcome, there are larger issues that threaten to undermine the management reform agenda and, in turn, reduce or eliminate recapitalization funds derived from management reform.

Management Reform at Risk?

The current defense management reform agenda is driven by three factors: (a) to align changed business practices with force transformation; (b) to generate resources internally to support recapitalization and investment in future combat systems; and (c) to reduce internal pressures on the defense budget as well as to respond to external pressures on the defense budget. If these imperatives are as strong as they appear, what then could undermine the current reform effort and make it unsustainable? There are four clear possibilities.

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[4] For a more thorough description of current reform efforts, see (Dawe & Jones, 2005) and (DoD, 2006b).

1. War Costs. If operations in Iraq and Afghanistan persist, costs associated with the base defense budget and the war effort will continue to diverge—particularly if war funding continues to be provided through non-traditional budget "bridges" and supplemental appropriations, a pattern unseen in the budgeting for past wars (CRS, 2006a). In this case, management associated with the base budget will operate in an increasingly constrained environment, while unconstrained spending will continue to be associated with the war. This is hardly an environment that will drive culture change and cost management throughout the organization. Moreover, these conditions invite the migration of base budget functions to the less constrained and less cost-managed war budget—resulting in distortions in the base budget that will affect future budget decisions.

2. Losing the Vision. Alternatively, Congress could demand that appropriations for the war efforts migrate to the base budget. In that case, it is likely total defense resources will erode as they are combined and become more transparent. Thus follows the second possibility: losing the reform vision to current-year "budget drills" to meet unfunded needs or to fill budget "wedges" in the execution year. Successful reforms may depend on demonstrating that the cost reductions and management reforms have generated the desired savings *and that the savings have been applied to the stated objective*. Failure to sustain or account for the results can lead to a loss of credibility for senior leaders (Roberto, 2005). If budget reductions cause the recaptialization goals to disappear in favor of simply meeting reduced budget targets, much of the motivation for reform could be lost.

3. Change Fatigue. "Repetitive Change Syndrome" is experienced when organizations too frequently adopt change initiatives. Such frequency generates chaos, burnout, and incapacity to make further change, thus, harming daily operations (Abrahamson, 2004). Observers warn against adopting change initiatives too frequently (Abrahamson, 2004). Defense management reform has been a continuous theme for over twenty years. Sustaining transformation could now depend on learning more about how the organization perceives the change agenda through analysis of communications and feedback and by examining the knowledge, attitudes, and actions of the receptors of communications about transformation.

4. Leadership Change. Leaders change frequently in the DoD among both uniformed and senior civilian leaders. It often appears that management reform initiatives do not survive leadership transitions, notwithstanding the success or failure of any particular reform initiative. The current Administration is in its final two years; sustaining its management agenda beyond the election horizons may not be a high priority in the permanent DoD bureaucracy. A new management agenda will replace the current "transformation" agenda, though the next administration will almost certainly face the same challenges to find more efficient defense business-management practices and seek reinvestable cost savings from these efficiencies. Learning to institutionalize the principles and processes of management reform will be important to future leadership transitions. We recommend a research and education project to facilitate the sustainment of improvements in defense business management practices through the expected leadership transition of 2008-2009.

Management Reform in a Declining Budget

How then should management reform be considered, if budgets are likely to decline and significant organizational risk factors threaten sustainment of defense business-management reform initiatives?

Efficiency-seeking management reforms will be insufficient to make up the budget shortfall. Claimed cost savings can be initially impressive. For instance, the Naval Air Systems Command claims FY 2007 savings-to-date amounting to 13.9 million—composed of permanent cost reductions ($6.1 million) and potential cost reductions from improved practices ($7.8 million) (Navy, 2007c). Overall, the Navy's business transformation advocate claims combined savings from Sea Enterprise initiatives of $27.7 billion from FY 2003-2005 (McCarthy, 2006). In both cases, some of the savings are realized in current-year operations; more are the result of projected cost reductions and revised future spending requirements. Nevertheless, these savings are not likely to close the budget gap if defense budgets decline and there is insufficient evidence to indicate whether any of these savings can be tracked to reinvestment in capital accounts. Even if efficiency-seeking savings reduce a significant portion of the internally generated fiscal stress, cost-reduction measures through management initiatives will not likely close the entire fiscal gap because they only address the internal sources of stress. The external sources are untouched by efficiency savings. Moreover, cost reductions are dispersed throughout the organization, are difficult to harvest, and are likely to be hoarded by middle managers in the face of tight resources. Savings in current-year budgets are likely to be redirected to under-funded current requirements.

Good management does not attract resources. There is little evidence to suggest that good management is rewarded with larger budgets. Resource-allocation decisions are policy choices among competing demands. Good management reduces the demand and may lead to reduced marginal future resource bases. Even the movement toward performance budgeting in the federal government leaves unclear the link between performance and resource allocation (Miller, Hildreth, & Rabin, 2001). Budgets simply do not grow because an agency gets a clean audit opinion or reengineers business practices.

If efficiency-seeking business-management reform cannot be viewed as a solution to declining defense budgets, how should the DoD view the rationale for sustaining management reform initiatives? There are three strong imperatives for sustaining an effective management reform agenda:

Continuous efficiency-seeking management improvement in the DoD should be understood as driven by stewardship concerns and the requirements of the operating forces. The DoD has the responsibility to the President, the Congress and the public to be a good steward of the highly material portion of the federal budget it manages. There is a justified expectation that the DoD will manage its resources well. The DoD also has a responsibility to support efficiently the varied requirements of the operating forces: people, systems, weapons, materiel. The policies and processes of management reform must align with operational requirements, especially as force transformation increases pressure on the business side of the department.

Large budget reductions can only be met by truly transformational responses. Despite the rhetoric of "transformation," the history of management reform in the DoD has been a model of incremental continuous change. A large decline in the defense top-line can only be met by transformational changes that take functions AND costs out of the department permanently. Major productivity improvements through consolidations, divestiture of both functions as well as assets, cancelled programs, and sharply reduced personnel would have to be achieved.

The acquisition community must view itself as a participant in cost-focused management reform rather than as a beneficiary. Rising acquisition costs are a major source of internal fiscal stress for the DoD. It is unlikely that cost reductions in other internal areas (such as personnel

or operations and maintenance) can possibly generate savings that will match the current growth in capital costs, let alone provide funds for additional reinvestment. The acquisition community must focus on its own cost-reduction initiatives to help generate the funding needed for recapitalization.

Thus, the matter of sustaining management reform in a time of uncertain budgets can be approached as two questions, not one: What are the best budget-policy decisions regarding resource levels and allocation considering the salient internal and external factors? And how much and what type of management reform is needed to meet the standards of stewardship and to support the requirements of the operating forces?

Conclusion

We have both investigated business management reform in the Department of Defense as well as examined the question of uncertain defense budgets. It is evident that pressure on the defense top-line comes from both external sources and internal factors. We have argued that efficiency-seeking management reforms can only address the internal pressures on the defense top-line. We have identified specific threats to the sustainment of defense management reform in a time of declining budgets and have offered strategic propositions to consider when addressing management reform in a time of uncertain budgets.

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Panel 15 - Enhancing Contract Performance Outcomes

Thursday, May 17, 2007	Panel 15 - Enhancing Contract Performance Outcomes
11:15 a.m. – 12:45 p.m.	**Chair:** **Charlie Williams**, Deputy Assistant Secretary of the Air Force (Contracting) **Discussant:** **Domenico Cipicchio, Department of Homeland Security, Chief Procurement Office, Director, Contract Operations** **Papers:** ***The Cultural Revolution*** **Dean T. Kashiwagi**, Arizona State University, and **Nathan Chong**, US ARMY Medical Command ***Incentive Contracts: The Attributes that Matter Most in Driving Favorable Outcomes*** **Robert L. Tremaine**, Defense Acquisition University

Chair: Charlie Williams, a member of the Senior Executive Service, is Deputy Assistant Secretary for Contracting, Office of the Assistant Secretary of the Air Force for Acquisition, Headquarters U.S. Air Force, Washington, D.C. Mr. Williams is responsible for all aspects of contracting relating to the acquisition of weapon systems, logistics support, materiel and services for the Air Force. Additionally, Mr. Williams is the U.S. member to the North Atlantic Treaty Organizations Airborne Early Warning and Control Programme Management Organizations Board of Directors.

Mr. Williams was born in Nashville, Tenn. He holds a bachelor of science degree from Middle Tennessee State University, Murfreesboro, and a masters degree from Tennessee State University, Nashville. He is also a 1996 graduate of the Industrial College of the Armed Forces, where he earned a second masters degree in national resource management. In addition to his formal education and training, Mr. Williams was assigned to the General Electric Aircraft Engines Division, Cincinnati, Ohio, as a member of the Education With Industry Program.

Mr. Williams entered federal service in 1982 as a member of the Air Force Logistics Command Mid-Level Management Training Program at Kelly Air Force Base, Texas.

Discussant: Domenico Cipicchio, Department of Homeland Security, Chief Procurement Office, Director, Contract Operations

The Cultural Revolution

Presenter: Dean T. Kashiwagi, is a professor at Arizona State University's Del E Web School of Construction and the Director of the Performance Based Studies Research (PBSRG) since 1992. PBSRG is the worldwide leader in improving construction performance and efficiency. Kashiwagi has developed a "hands off" approach to managing contractors/vendors in the construction industry or in any industry. His concept is contrary to traditional price-driven construction procurement. It forces the contractor/vendor to be accountable—in other words, minimizes risk for the facility owner. The technology has been tested over 450 times totally, using $521M in construction projects with a 98% success rate (on time, on budget, and high quality). This is one of the few documented processes that brings better value for the owner and maximizes the profit of the contractor. It is currently being tested in other professional areas outside of construction.

Presenter: Nathan B. N. Chong, Chief, Facility Life Cycle Management Division, US Army Medical, has been involved with over $1Billion worth of Army medical and research renovation and new construction projects around the world for the past 22 years. He has a MS in Environmental/Civil Engineering from George Washington University and a BSCE in Civil Engineering, Purdue University. Nathan is a license Professional Engineer in the State of Hawaii, Project Management Professional (PMP) Certified, and Acquisition Level II Certified—Facilities Engineering with the US Department of Defense. He facilitated the implementation of Performance Information Procurement System (PIPS) within the Army Medical Facility acquisition system. His career objective is to improve the Army medical design and construction processes.

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Abstract

The culture within the Federal Government Acquisitions is based on the *Federal Acquisition Regulations* (*FAR*) and its interpretation, often placing organizations/agencies in the cultural environment of the price-based environment. In the healthcare system, clients depend on the qualifications and expertise of the design and construction team to meet their specific needs and requirements. The hiring criteria of these experts have been primarily based on low bid or relationships, and have continuously resulted in poor performance. The US Army Medical Command (MEDCOM) (contracting approximately $100M in medical renovation awards per year) partnered with the Performance Based Studies Research Group (PBSRG) at Arizona State University to create and test an information environment to assist in alleviating some of its

cultural inefficiencies. The developed information environment minimized the flow of information, forced the contractors to concentrate on value and the assumption of risk, and stimulated an atmosphere of accountability. Through the system, the client's internal bureaucratic resistance was minimized; and, without controlling the various contract/procurement processes, MEDCOM leadership has gained control of the performance of their infrastructure revitalization program by implementing a cultural environment of information.

Introduction

The Performance Based Studies Research Group (PBSRG), experts in the area of performance information, has used the Construction Industry Structure (CIS) diagram to define and compare the characteristics of the high-competition environments: Price Based and Value Based (Figure 1). The best-value environment focuses on securing the best-value vendor for the owner and on transferring all project risk to the outsourced expert. It considers the vendor's past performance, ability to identify and minimize risk, preplanning foresight, and project knowledge. It requires the contractors to use their expertise to complete a project that fulfills the intent of the owner, and minimize controlled project risk at the beginning of the project. It forces accountability between all parties, and benefits vendors with foresight, experience, skill, and efficiency. It provides an environment that maximizes contractor profit, while minimizing owner resources.

In contrast, the price-based environment focuses on using minimum standards to define the requirement of the contract, in order to ensure that the minimal requirement is met. Due to its concentration on price, it encourages the contractors and vendors to translate the minimum requirement to a maximum in attempts to lower the quality of the delivered product to gain the competitive advantage. This penalizes the high performers who can see the prospective project from a visionary view, from beginning to end, and seeks to minimize change orders by pricing in items which will need to be done that are missing from the specifications. It discourages the use of expertise, and asks the contractor/vendor to price only what is written—ignoring the owner's intent. It promotes project dependency on change orders when the unspecified or client "unexpected" events occur during project execution.   The price-based environment gives inexperienced contractors the competitive advantage over experienced contractors, thus driving the experienced contractors to move from a position of minimizing risk to a position of ignoring project risk. This culture results in the contractor relying on the client to manage, direct, control, and inspect, and become reactive instead of proactive. This trend, which is clearly demonstrated in Figure 2, has the following ramifications:

1. Penalizes contractors who carefully preplan, understand the scope of the project, and price-out the project.

2. Motivates contractors to take the low price at the last minute, not knowing whether they are meeting the specifications, and when receiving the award, further price shopping to ensure that they can meet the specifications for the lowest possible price.

3. Encourages all manufacturers to ensure that their products meet only the lowest possible quality to get the largest possible volume sales of contractors trying to get the lowest price.

4. Promotes the bypass of education and personnel training in the industry, leading to a critical shortage of trained personnel.

5. Leads to poor construction performance (not on time, not on budget, and not meeting the client's expectations).
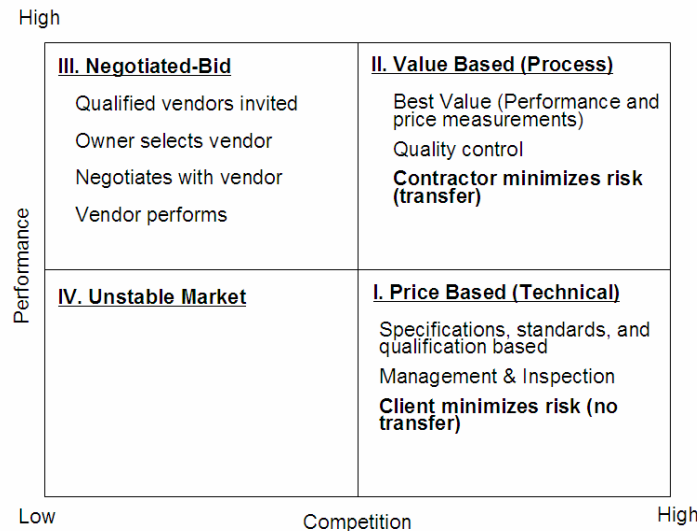
Figure 1. Construction Industry Structure (CIS)
(Kashiwagi, 2004)
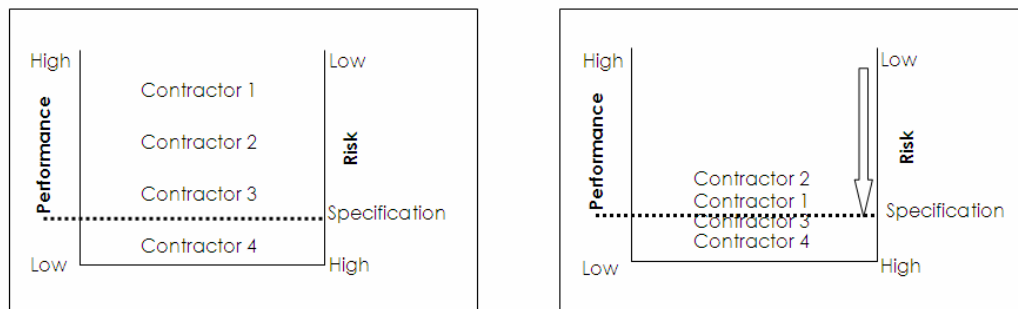
Figure 2. Impact of Price-based Bidding: Increase of Risk
(Kashiwagi, 2004)

Relative Analysis of the Two Environments

A relative analysis of the two environments (price based and best value) leads to the following deductive conclusions. Performance can only occur when risk is transferred to an entity that has the capabilities of minimizing the risk. The best-value environment ensures high performance by transferring risk to the best-value contractor who can verify past performance, send their best personnel, identify risk that they control and do not control, and develop a plan to minimize the risk that they do not control. The owner's resulting risk in this environment (assuming that the client did pick the best value—highest performer for the lowest price), is the interface or the seam between the client and the contractor, or in other words the risk that the contractor does not control (Figure 3). Alternatively, the price-based environment passes risk to

the contractor with the lowest price without ensuring that they can minimize the risk, hence: the poor performance of the construction industry.

When risk is transferred to a party unable to minimize the risk, the party must be managed, inspected, and controlled. In consequence, the owner's risk in the low-price environment is the potential that the minimally trained, managed, and directed contractor/vendor may not do what they are directed to do (Figure 3). The price-based environment has reflected this, in a heavy overhead for transaction costs relating to management, direction, control, inspection, and communications that would be eliminated if the client's process were more efficient. This has also translated to a higher requirement of people needed to maintain the system (due to the inefficiency of the process). Accordingly, there is more confusion in the price-based environment due to the management, decision-making, unrealistic expectations, attempts to control others, use of leverage (making a party do free work or work that they are incapable of doing), and the lack of performance information of key individuals, contractors, and the client's personnel. Without simple, easy-to-understand measurements that consider the vendor's capabilities, the price-based environment is adversarial: where every participant, regardless of whom they work for, protects themselves before they protect the company they work for, or the client/user for whom the construction is being built.
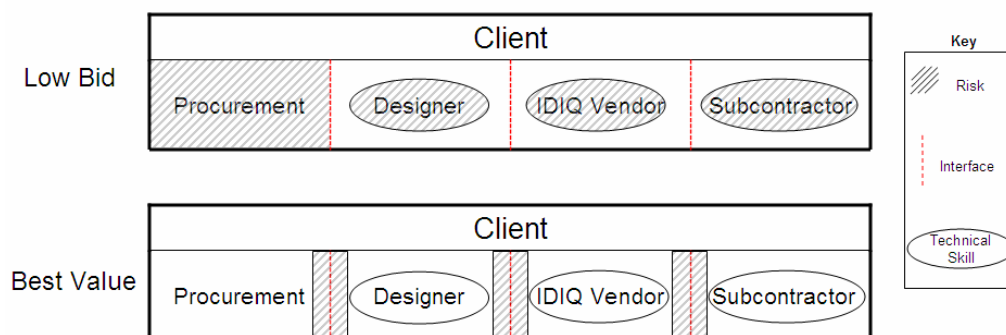
Figure 3. Difference in Risk Between Price-based and Best-value Environments

The above characteristics are supported by documentation of construction delivered by the price based environment (AGC, 2005; Butler, 2002; CII, 2005; Doree, 2004; Fitz-Gibbon et al., 2006; Guo, 2006; Markus, 1997; NDU, 2005; Post, 1998; State of Hawaii, 2002). The characteristics identify management as the key component to the price-based environment; and leadership, or the alignment of resources that can minimize risk as the key component to the best-value environment. The understanding of the Construction Industry Structure (CIS) and the impact of the price-based bidding identifies the following leadership/management characteristics as well as the projected goal of personnel who are trying to move from the price-based environment (management and control) to the best-value environment (leadership):

Management

1. Focus on relationships

2. Lack of performance information on critical elements of the contractor's team (relative ability to finish on time, on budget, and meet the client's expectations)

3. Direction/Control by client's personnel

4. Decision-making performed by client's personnel instead of contractor personnel

5. Maximum communication/documentation passed between client and contractors

6. Duplication of cost estimates quantities and approvals

7. Passing of risk without regard to relative ability to minimize risk

8. The most important person in the process becomes the client's procurement agent—although they have no technical expertise and take no responsibility for cost or time overruns

Leadership

1. Performance information used to minimize decision-making

2. Transfer of risk to those that can minimize risk

3. Replacement of the client management, direction, and inspection with contractor/vendor self- documentation/regulation

4. Minimization of client decision-making, documentation, and flow of information

5. Process installed to ensure that the best-value contractors/vendors know how they will minimize risk

6. Contractors/vendors address performance and risk in terms of value chain, supply chain, and overall transaction costs

Information Measurement Theory and Best Value Test Results

PBSRG has been testing best-value procurement using an information based Performance Information Procurement System (PIPS). PIPS is built on a foundation of principles outlined by the Information Measurement Theory (IMT). IMT is a set of deductive logic models which predict future results based on relative measurements. The following are the major concepts or models (Kashiwagi, 2004):

1. Decision-making requires individuals to use their subjective bias and experience to solve a situation in which they have insufficient information to predict an outcome.

2. Decision-making brings risk.

3. Decision-making is minimized when the decision-maker has accurate information.

4. Dominant information is information that will minimize the need for decision-making.

5. It is difficult for one organization/person to control the actions of another individual.

6. People and organizations are predictable with enough information.

7. Past performance and future capability to perform on unique events can be predicted.

8. Experienced personnel can identify future activities in an event before it happens. They can identify and prioritize risk, and they will have a plan to minimize the risk before it happens.

The following test results and measurements of PIPS have validated the above concepts:

1. Duration of testing: 13 years.

2. Research Funding: $6.2M

3. Number of tests: 480

4. Construction volume/scope of tests: $500M

5. Largest projects: $100M City of Peoria Wastewater Treatment DB project (2007) and the $53M Olympic Village/University of Utah Housing Project (2001)

6. Performance of contractors in tests (on time, on budget with no contractor-generated cost change orders, meeting client's expectations): 98%

7. Surprise factor of nonperformance: Less than 1%

8. Management effort of client's construction managers: minimized by 80 to 90% (University of Hawaii (2000) and University of Minnesota (2006), and the ability of project managers to deliver 10 times the amount of projects (State of Hawaii (1997-2001)

9. Awards: 2005 Corenet Global Innovation of the Year Award for testing at Harvard University, and the 2000 Tech Pono Award for the testing at the State of Hawaii

10. Clients in the Public Sector: FAA, US Army Medical Command, USCG, States of Washington, Wyoming, Utah, Georgia, Hawaii, and Missouri, City of Peoria, AZ, City of Miami Beach, and Universities (University of Hawaii, Arizona State University and University of Minnesota)

11. Clients in the Private Sector: General Dynamics, Raytheon, Schering Plough, United Airlines, Motorola, Honeywell, IBM, Boeing, Intel, and International Rectifier

12. Risks and Reason for Stopping PIPS: the champion/expert of Best Value/PIPS moves or retires, political change, someone in the organization feels threatened and stops process, organization is too inefficient, ineffective, and bureaucratic to make process work

Theoretical Concepts of Best Value

The Best Value/PIPS process (shown in Figure 4) is composed of three primary steps:

1. Selection Phase (Filter 1-4): Identification of the Best Value

2. Preplanning /Quality Control Phase (Filter 5): Forcing the best value to preplan and minimize risk that they control and do not control through a PIPS Quality Control Plan or Risk Plan and schedule

3. Risk Management Phase (Filter 6): Management of the construction project through risk minimization

The selection phase attempts to differentiate the performance and expertise of competing vendors. This is done through the collection of each contractor's past performance information (from key individuals as well as the general contractor and critical subcontractors), risk-assessment/value-added plan, and interview ratings. It is important to note that if the contractors cannot differentiate themselves through their past performance, identification of project risk out of their control, plans to minimize uncontrolled risks, value added options, and interview, there is nothing wrong with awarding the project based on the best price (as the

contractors proved they are all the same). The client should not make decisions to assist any contractor to become competitive. No contractor should be assisted by being given a second chance, redoing their cost estimate, or given information from other contractors that could possibly make them more competitive. In best value, every contractor is competitive, and every contractor has a chance to differentiate themselves without biased assistance from the client's representative.
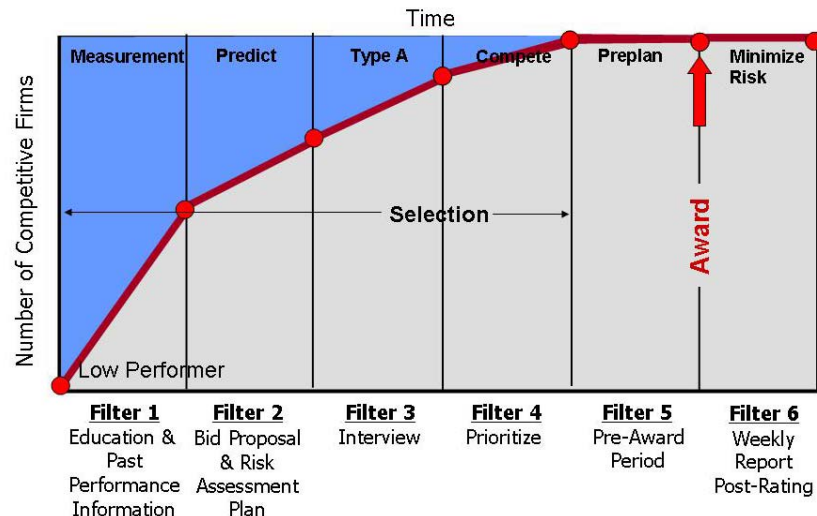
Figure 4. Best Value Natural Selection
(Kashiwagi, 2004)

The Best Value/PIPS process forces the best-value contractor to take its price, risk-assessment/value-added plan and interview statements into the second phase of Preplanning/Quality Control. In the preplanning/PIPS Quality Control Phase, the contractor concentrates on minimizing the project risks. A schedule listing the major milestones in the project is developed. A QC plan is also compiled by the contractor which includes a list of risks out of the contractor's immediate control in conjunction with a detailed plan to minimize each risk. Technical risks are not included, as the contractor minimizes risks that it controls by meeting the requirements of the specification. Only after the owner is satisfied with the pre-planning performed by the contractor will the contract be awarded.

Once the project has been initialized, the contractor enters the Risk Management Phase. Every week during project execution, the contractor is required to submit a Quality Assurance (QA) plan and Weekly Report to the owner. The QA plan is a checklist of the risks identified in the previous phase that ensures that each risk is being monitored and minimized according to the directives included in the QC plan. If the risk cannot be minimized according to client pre-approved QC efforts, the risk is reported on the weekly report along with unforeseen risks adversely impacting the schedule or budget. The client is then obliged to pay for additional time and effort (Figure 5). This process transfers the risk to the contractor, who then uses the mechanism of the QC plan to make all parties accountable thorough communication, coordination, and preplanning.
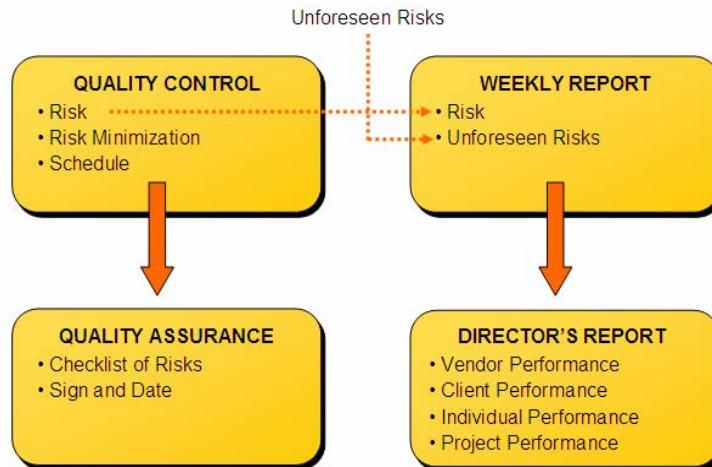
Figure 5. Information Environment

The selection process ensures the procurement of the best-value contractor and the transfer of all project risk to the contractor. The QC plan and the weekly risk report then defend the high-performing contractor by identifying risks out of the contractor's control and the contractor's limited abilities to impact the risk. Because it is reviewed by the client's representative, the information is usually very accurate. The QC plan, QA checklist, weekly report, and schedule, also help to regulate the contractor's work. All the elements are incorporated into the contractor's contract on award. At the end of the project, the contractor is rated by the owner, and the rating modifies the past performance rating of the contractor by 50% (Figure 6).
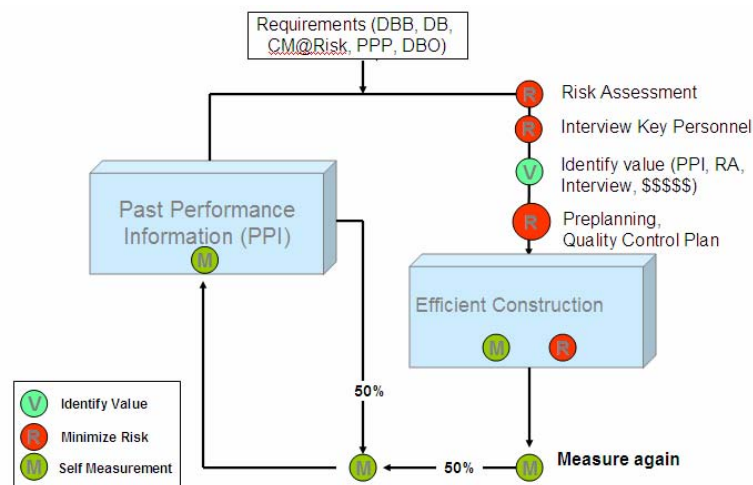
Figure 6. Best Value DMAIC Closed Loop
(Kashiwagi, 2004)

Information System

The owner is able to compile a group of individual contractor weekly reports (spreadsheets submitted to the client weekly) into a Director's Report (Figure 7) which can give a Facility/Construction director valuable measurements of risk/performance for the organization

as a whole, as well as a prioritization of the risks. The Director's Report also allows for the comparison of contractors, project managers, project integrators, inspectors or design professionals involved in the projects. The report provides accurate, timely risk/performance information that disables bureaucracy and identifies where risk is being created. For the first time, it gives a director a simplistic information system with minimal maintenance that deters nonperformance by highlighting nonperformance quickly and accurately.
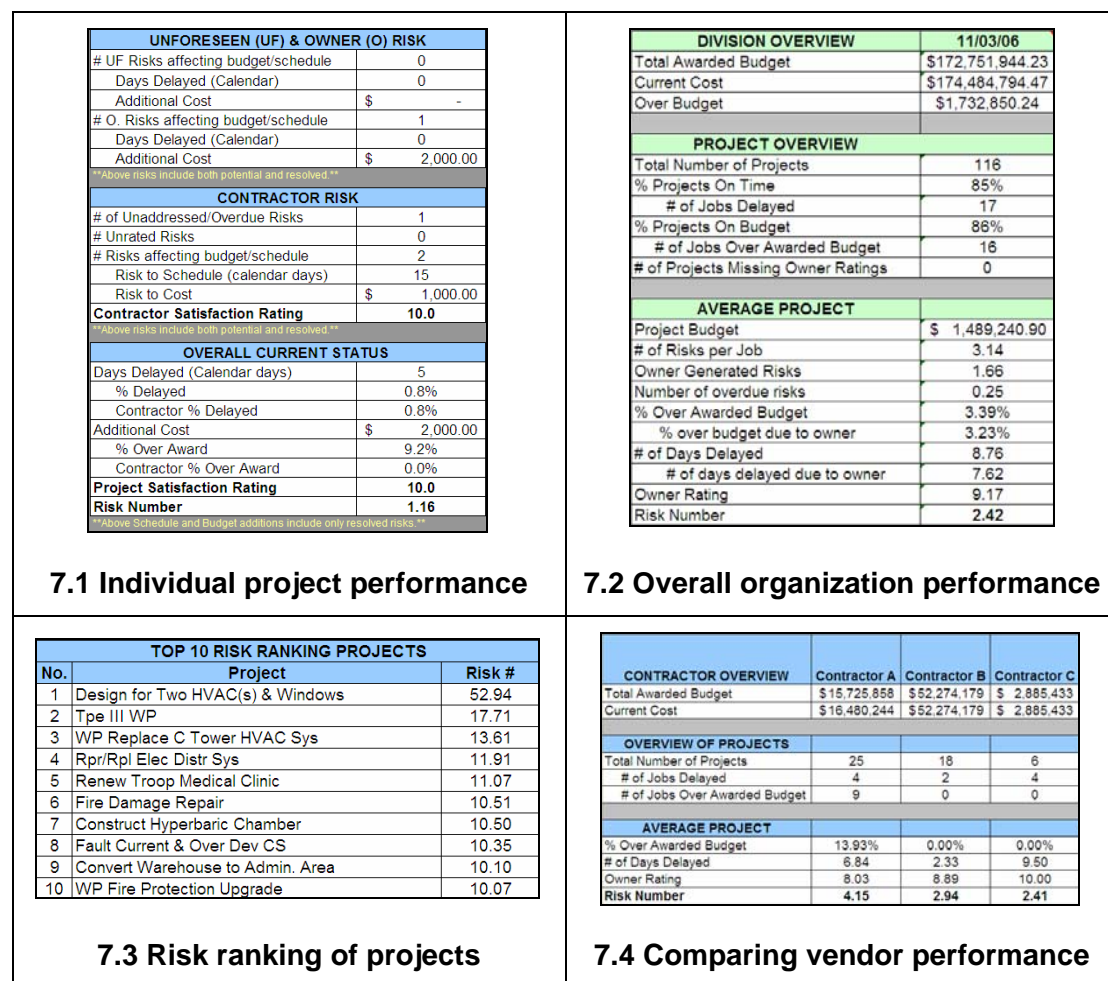
7.1 Individual project performance

UNFORESEEN (UF) & OWNER (O) RISK	
# UF Risks affecting budget/schedule	0
Days Delayed (Calendar)	0
Additional Cost	$ -
# O. Risks affecting budget/schedule	1
Days Delayed (Calendar)	0
Additional Cost	$ 2,000.00
Above risks include both potential and resolved.	
CONTRACTOR RISK	
# of Unaddressed/Overdue Risks	1
# Unrated Risks	0
# Risks affecting budget/schedule	2
Risk to Schedule (calendar days)	15
Risk to Cost	$ 1,000.00
Contractor Satisfaction Rating	10.0
Above risks include both potential and resolved.	
OVERALL CURRENT STATUS	
Days Delayed (Calendar days)	5
% Delayed	0.8%
Contractor % Delayed	0.8%
Additional Cost	$ 2,000.00
% Over Award	9.2%
Contractor % Over Award	0.0%
Project Satisfaction Rating	10.0
Risk Number	1.16
Above Schedule and Budget additions include only resolved risks.	

7.2 Overall organization performance

DIVISION OVERVIEW	11/03/06
Total Awarded Budget	$172,751,944.23
Current Cost	$174,484,794.47
Over Budget	$1,732,850.24
PROJECT OVERVIEW	
Total Number of Projects	116
% Projects On Time	85%
# of Jobs Delayed	17
% Projects On Budget	86%
# of Jobs Over Awarded Budget	16
# of Projects Missing Owner Ratings	0
AVERAGE PROJECT	
Project Budget	$ 1,489,240.90
# of Risks per Job	3.14
Owner Generated Risks	1.66
Number of overdue risks	0.25
% Over Awarded Budget	3.39%
% over budget due to owner	3.23%
# of Days Delayed	8.76
# of days delayed due to owner	7.62
Owner Rating	9.17
Risk Number	2.42

7.3 Risk ranking of projects

TOP 10 RISK RANKING PROJECTS		
No.	Project	Risk #
1	Design for Two HVAC(s) & Windows	52.94
2	Tpe III WP	17.71
3	WP Replace C Tower HVAC Sys	13.61
4	Rpr/Rpl Elec Distr Sys	11.91
5	Renew Troop Medical Clinic	11.07
6	Fire Damage Repair	10.51
7	Construct Hyperbaric Chamber	10.50
8	Fault Current & Over Dev CS	10.35
9	Convert Warehouse to Admin. Area	10.10
10	WP Fire Protection Upgrade	10.07

7.4 Comparing vendor performance

CONTRACTOR OVERVIEW	Contractor A	Contractor B	Contractor C
Total Awarded Budget	$15,725,858	$52,274,179	$ 2,885,433
Current Cost	$16,480,244	$52,274,179	$ 2,885,433
OVERVIEW OF PROJECTS			
Total Number of Projects	25	18	6
# of Jobs Delayed	4	2	4
# of Jobs Over Awarded Budget	9	0	0
AVERAGE PROJECT			
% Over Awarded Budget	13.93%	0.00%	0.00%
# of Days Delayed	6.84	2.33	9.50
Owner Rating	8.03	8.89	10.00
Risk Number	4.15	2.94	2.41

Figure 7. Director's Report

Implementation of Best Value/PIPS in the US Medical Command (MEDCOM)

In order to implement Best Value/PIPS into the US Medical Command (MEDCOM), the system was adjusted in order to assure compatibility with the FAR and AFARS. As a result, the following changes were made:

1. The preplanning/quality control period is performed during a preconstruction period *after* the award of the contract.

2. The technical and non-technical concerns of the client/user are given to all contractors.

The Best Value/PIPS process can be implemented on Design-Build, CM@Risk, Design-Bid-Build, IDIQ contracts, or on designers. The US Army Medical Command has implemented it on IDIQ contracts, and directed the contractors to use a best value process that includes preplanning, Quality Control that minimizes risk that the contractor does not control, weekly risk reporting, and client identification of contractor performance.

Once the IDIQ contractors had been educated in the Best Value process, they began to realize that it would assist them to be more efficient, make the client's/user's representatives accountable, and maximize their profits without charging more (win-win). The contractors began to realize that the process was a very successful enterprise model that used best business practices, motivated their personnel to improve, and measured their own performance. The majority of the contractors began requesting their personal performance measurements.

The US Army Medical Command effort has grown in stages:

1. First stage: MEDCOM officials supported the system, instituted training sessions for their own personnel, and introduced the contractors to the process (duration of 1 year).

2. Second stage: MEDCOM instituted the system into their specifications, making it a requirement to select on best value, preplan the minimization of risk, implement a contractor generated QC plan, and measure performance. Five out of a potential seven IDIQ contractors attended the annual Best Value conference, which included detailed training of the system, at their own expense. The contractors viewed it as a process required when working with MEDCOM (duration of 1 year).

3. Third stage: The information environment and Director's Report were instituted. Performance information was returned to the IDIQ contractors on both project performance and ongoing risk minimization. The contractors noted that the Best Value/PIPS structure allowed them to perform, differentiate themselves based on value, and increase efficiency. Irresolvable project problems which previously have migrated to the director of the MEDCOM, have now been minimized to problems with easily identifiable solutions. Four of the seven contractors generated their own training and measurement systems. Six of the seven contractors attended the annual Best Value/PIPS training education at their own expense. One of the contractors began using their performance information to educate other owners on the efficiency and effectiveness of the Best Value/PIPS structure. Contractors now view the Best Value process as a process to measure themselves, minimize their risk, and improve their companies (duration of 1 year).

4. Fourth stage (current stage): Continuous education of the concepts of supply chain optimization, preplanning, quality control, and risk minimization are being facilitated. Both the client's personnel (MEDCOM representatives, the Corps of Engineers (COE) procurement personnel, and users) and the contractor's personnel are learning how to maximize the effectiveness of the system instead of using them as routine additional duties.

Federal Acquisition Regulation (FAR)

The intent of the *Federal Acquisition Regulation* (*FAR*) (2002) is to bring the government the "best value." In the delivery of construction, the *FAR* recommends sealed bids. However, in *FAR* 36.103b and 6.04(b)(1), it states that if the use of sealed bids cannot effectively deliver the best value, the request for proposal process using criteria other than price can be used. There is ample evidence that implies the delivery of construction cannot be treated as a commodity.

The term "best value" is mentioned 34 times, and the term "low bid" is mentioned 19 times in the *FAR*. Best Value means: the "expected outcome of an acquisition that, in the estimation of the Government, provides the greatest possible benefit to the requirement" (*FAR* 2.1). The benefits include (FAR 102.2(b)):

1. Satisfy the customer in terms of cost, quality, and timeliness of the delivered product or service by, for example—

   - Maximizing the use of commercial products and services;

   - Using contractors who have a track record of successful past performance or who demonstrate a current superior ability to perform; and

   - Promoting competition;

2. Minimize administrative operating costs;

3. Conduct business with integrity, fairness, and openness

   FAR 1.102.2-1 (b) states:

   (b) *Vision.* All participants in the System are responsible for making acquisition decisions that deliver the best value product or service to the customer. Best value must be viewed from a broad perspective and is achieved by balancing the many competing interests in the System. The result is a system which works better and costs less.

   FAR 1.102-2(b)(2) states:

   (2) The System must provide uniformity where it contributes to efficiency or where fairness or predictability is essential. The System should also, however, encourage innovation, and local adaptation where uniformity is not essential.

   FAR 1.102-4 (e) further states that:

   (e) The *FAR* outlines procurement policies and procedures that are used by members of the Acquisition Team. If a policy or procedure, or a particular strategy or practice, is in the best interest of the Government and is not specifically addressed in the *FAR*, nor prohibited by law (statute or case law), Executive order or other regulation, Government members of the Team should *not assume it is prohibited.* Rather, absence of direction should be interpreted as permitting the Team to innovate and use sound business judgment that is otherwise consistent with law and within the limits of their authority. Contracting officers should take the lead in encouraging business process innovations and ensuring that business decisions are sound.

The *FAR* addresses the use of the PIPS filters of past performance (*FAR* 15.305(a)(2)), the risk-assessment plan/value-added plan (*FAR* 15-305(a)(3)(i)), and the interview (*FAR* 15.102). The *FAR* addresses prioritization of alternatives in 15.305 Proposal evaluation:

> Proposal evaluation is an assessment of the proposal and the offeror's ability to perform the prospective contract successfully. An agency shall evaluate competitive proposals and then assess their relative qualities solely on the factors and subfactors specified in the solicitation. Evaluations may be conducted using any rating method or combination of methods, including color or adjectival ratings, numerical weights and ordinal rankings. The relative strengths, deficiencies, significant weaknesses, and risks supporting proposal evaluation shall be documented in the contract file.

However, the Army *FARS* has the following:

> 5115.304—Evaluation Factors and Significant Subfactors
>
> (iv) Must be qualitative. Numerical weighting (i.e., assigning points or percentages to evaluation factors and subfactors) is not an authorized method of expressing the relative importance of these factors and subfactors. Evaluation factors and subfactors must be definable in readily understood qualitative terms (i.e., adjectival, colors, or other indicators, but not numbers) and represent the key areas of importance to be considered in the source selection process. The direction of this subparagraph is not waivable, either on an individual or class basis, as an *AFARS* deviation.

Therefore, when selecting a contractor, *AFARS* Best Value process must not use either weights or the ratings on any of the evaluation factors must have qualitative ratings. The impact of this policy is the lack of transparency but also prevents protests due to the inability or difficulty to challenge a subjective, nontransparent system. The downside to this type of system is that it motivates owner representatives to make decisions instead of allowing the contractors to determine who gets the project based on a preset system that is very predictable. However, Best Value/PIPS can still be run using qualitative ratings on past performance, risk assessment/value added submittal, and interviews.

The major contribution of Best Value/ PIPS is in the Preplanning/QC phase and the Risk Management phase. These two phases can be written into the IDIQ specification. The phases provide the user with relevant information related to the contractor's performance. These components are not a procurement issue, but a client's requirement to ensure wise usage of their funding. This responsibility must be fulfilled and is periodically checked by auditors to ensure the funds are receiving the best value for the government.

Resistance to Change

The movement to Best Value is threatening to the status quo due to the following:

1. The contractor becomes the expert, the center of the universe, the most important component of the value chain, replacing the perch the procurement officer has in the low-bid environment.

2. Best Value/ PIPS forces the government to release control to the outsourced vendor. It is difficult for procurement agents to release control.

3. If services are outsourced, and the process becomes more efficient and effective, the government will need less personnel to make it work. This threatens the procurement community, whose members may feel that their jobs are being eradicated.

4. A change in culture brings fear to the government community. This fear is exhibited in many ways: resistance to change, not being open to logic/best practices, using the *FAR* and *AFARS* and interpreting new concepts as illegal, increasing transaction costs of other participants in the delivery chain, and not acting in the best interest of the government.

   Resistance to using the Best Value/PIPS process has included:

1. Stating that Arizona State University could not be used to replace the COE procurement process. This is a fear that is totally unjustified. ASU is a research/education group. ASU does not participate in the procurement selection.

2. Best Value/PIPS will only quantify contractors with past performance. This is incorrect. If a contractor has no past performance ratings, the client is instructed to rate them an average rating. This rating is called "I don't know." The contractor could be a very high performer based on the owner's past experience; however, the client should not bias the system by making a decision and helping a contractor get in.

3. The past performance is only good past performance. In order to win a true best-value RFP, the contractor must send their best people, and, therefore, their best past performance. In this case, the best past performance is indicative in the way the best value will operate. This minimizes client decision-making, forces the competition among performers, and allows the transfer of risk to the best performer.

4. Risk-assessment plans are general and ambiguous. As contractors get grounded into the system of identifying the risks that they do not control, the risk plans will get better. However, they can only add to the contractor's preplanning and thinking and do not act as a detriment.

5. Interviews should focus on technical matters. In order to rate contractors on technical matters, the government has to be the expert, make decisions, and, therefore, absorb the risk. This system has proved to be unsuccessful. Contractors who can answer concerns simply, in non-technical language, are high performers. Poor performers cannot simplify.

6. There is a lack of competitive range and discussions. The competitive range should be identified by the best values.

7. The scope of the project should not be published in terms of budgets. Best Value/PIPS encourages giving the budget to the contractors so they may determine risk. However, giving the budget is not mandatory. Not giving the budget often helps the low bidders who gain the advantage with low price. High performers always minimize risk, and if any information is withheld, the risk increases, and the high performers increase their prices.

8. Sharing of offerors' risk plans with other contractors is not required.

Conclusion

Best Value/PIPS is a cultural revolution for the government. The process/structure has been well tested over an extended period of time. Best Value/PIPS requires the procurement agents to release control, minimize decision-making, minimize the creation of transaction costs, and change their thinking. Education is the key. The government needs to become more efficient and effective.

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Incentive Contracts: The Attributes that Matter Most in Driving Favorable Outcomes

Presenter: Robert L. Tremaine, is an Associate Dean for Outreach and Performance Support at the Defense Acquisition University's West Region campus in San Diego, CA. He is an Air Force Academy graduate and holds a Master's of Science in Systems Management (Research and Development) from the Air Force Institute of Technology. He is a retired Air Force colonel with over 25 years' experience in air, missile, and space weapon systems acquisition.

Abstract

Incentive contracts have been in place for many years. They represent just one of many contractual tools the Department of Defense has at its disposal to drive certain performance behaviors. Lately, the usefulness of incentive contracts has come into question. The dividends have not been readily apparent. This research study set out to determine what generally afforded strong correlations between incentive-type contracts and expected performance outcomes. Twenty-five weapon system acquisition programs offices were interviewed in various stages of their acquisition lifecycles. A standardized questionnaire-survey was used to capture the data. This presentation prepared for the Fourth Annual Acquisition Research Symposium will address the findings and include a few key recommendations intended to better arm the acquisition workforce on the use of incentive contracts.

Discussion

In the past several years, major weapon system development programs have drawn significant attention. The reasons are varied. In some cases, costs have skyrocketed; schedules have experienced significant delays; and performance levels have failed to meet government expectations despite the employment of management tools designed to control costs, preserve schedules and influence performance outcomes. Some of these management tools (including contractual measures, as originally conceived and specified by the *Federal Acquisition Regulations* (*FAR*s)) can give tremendous flexibility to the implementation of government contracts. The use of such contractual measures is one of many handy tools in a program manager's toolkit to help drive performance behavior. However, the GAO recently identified an apparent disconnect between the use of certain measures like incentives and expected outcomes in weapon system acquisitions. In short, it appeared that incentives were not driving performance outcomes as originally envisioned.

So, what about incentives? Are they still a good tool to drive performance behaviors despite the recent criticism and doubt? Have organizations found a way to effectively apply incentives and demonstrate the usefulness of incentives? The answer to all of these questions is, "yes." There is no "one size fits all," but the incentive attributes that seemed to matter the most in influencing performance outcomes for the 25 programs, and generally afforded strong correlations between incentives and desired performance were indicated by the findings.

Conclusion

Strongly Communicated Expectations and Feedback: Frequent and unambiguous communication/feedback made a noticeable difference for incentive contracts. Even though incentive contracts require some additional administrative burden, the outcome justified the increased workload of feedback for most programs under this research review. Continuous and open dialogue at both junior and senior levels led to early discovery and timely reconciliation of many known issues and helped keep a program on track.

Metrics: The selection of key and enduring measures within an evaluation period and of measures that could be connected to subsequent evaluation periods made a noticeable difference for incentive contracts. Key measures can validate whether or not a program achieved certain necessary intermediate milestones along a program's critical glide path. They confirm program momentum. They served as an early warning system—a bell weather—and answer the age old question, "Are we on track"? They also fill a huge role as performance benchmarks. Those interviewed under this research project said when they effectively employed key measures, such tools also helped them navigate their program pathway despite the unavoidable programmatic turbulence. Their measures surfaced either as two types: <u>objective</u> and/or <u>subjective</u>. Without question, selecting the correct type of measures presented the biggest challenge. The ability to hard-wire them to achievable outcomes makes objective measures like Technical Performance Measures (TPMs), Cost Performance Indices (CPIs), Schedule Performance Indices (SPIs), etc., invaluable gauges. They served as tremendous forecasting devices when they were carefully connected to outcomes.

Base Fee: The incorporation of base fee in award-fee contracts made a noticeable difference. Of the 25 organizational interviews, many used some form of base fee on cost-plus-award-fee contracts. Numerous organizations implementing cost-plus-award-fee (CPAF) valued base fees as a leverage tool. Even though the *Federal Acquisition Supplement* (*DFARS*) *216.405-2*(c)(iii) allows up to 3% of the estimated cost of the contract exclusive of fee, a contractor could provide "best efforts" for the award-fee term and still receive no award. As a result, there was some pressure on the government to provide a portion of the award fee for "best efforts." Further, our research team found that senior defense industry personnel welcomed the use of base fee to better delineate the difference between "best efforts" (e.g., fee) and "excellence" (e.g., award).

Trained and Experienced Personnel: Training and experience made a noticeable difference for incentive contracts. Nothing seems to have a more dramatic impact in DoD like training and experience. Training draws it roots from practical experience. It's systematic. We learn from our successes and failures in the field and make adjustments accordingly in the way we train. The mantra, "we train like we fight and fight like we train" is pervasive within the warfighter arena and, ultimately, leads to advantages on the battlefield. Without question, practical experience helps build better training programs. It can overcome unforeseen shortfalls and the inevitable prevailing uncertainty even within proven systems. It's no different for incentive-type contracts. Organizations that had formalized instruction and/or coached their personnel on the use of incentives indicated such training more favorably influenced outcomes.

The exploitation of an increasingly popular collaborative medium called Communities of Practices (CoPs) on the DAU Acquisition Community Connection offers access to these particular techniques and an even wider array of current experiences and lessons learned regarding incentives ranging from the general to the specific. The DAU has already established a site on the ACC, Award and Incentive Fee Contracts. See

(https://acc.dau.mil/CommunityBrowser.aspx?id=105550). These and other collaborative training aids are critical because once an incentive strategy is in place, its maximum value truly depends on its ability to implement techniques that drive favorable outcomes. There's no better source of experts who face contract incentive challenges every day than the acquisition workforce who is charged with appropriately implementing the techniques that drive outcomes, appreciably.

Panel 16 - New Dimensions in Acquisition Management

Thursday, May 17, 2007	Panel 16 - New Dimensions in Acquisition Management
11:15 a.m. – 12:45 p.m.	**Chair:** **Lieutenant General Joseph L. Yakovac, Jr.**, USA (ret.), former Military Deputy to the Assistant Secretary of the Army for Acquisition, Logistics & Technology **Papers:** ***Capabilities Centric Acquisition: A System of Systems View of Acquisition Management*** **Colonel Raymond D. Jones**, USA, Aviation Project Manager, Modular Brigade Enhancements ***Lessons from Army System Developments*** **Richard G. Rhoades**, The University of Alabama, Huntsville, and **William A. Lucas**, Massachusetts Institute of Technology ***Too Little Too Soon? Modeling the Risks of Spiral Development*** **John Dillard**, Naval Postgraduate School, and **David Ford**, Texas A&M University

Chair: Lieutenant General Joseph L. Yakovac, Jr., USA (ret.), former Military Deputy to the Assistant Secretary of the Army for Acquisition, Logistics & Technology

Capabilities-centric Acquisition: A System of Systems View of Acquisition Management

Presenter: Colonel Raymond D. Jones, USA, Aviation Project Manager, Modular Brigade Enhancements

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While heeding the profit of my counsel, avail yourself also of any helpful circumstances over and beyond the ordinary rules.   *-Sun Tzu,* The Art of War

Introduction

The purpose of this paper is to begin a discussion on the need and complexity of managing the material acquisition process from a capability focused perspective. As warfighters develop doctrine, tactics, techniques, and procedures for the current and future fight, they do so from a joint and combined arms perspective. Battlespace success is viewed from the combined effects of multiple systems providing a synchronized force multiplier for the Commander. Conversely, our acquisition process remains trapped in a historical paradigm designed to meet Cold War requirements. This paper does not intend on offering the solution. This is merely a thought piece on perspectives from someone who is challenged daily with the opportunity of developing a capability management process for integrating future capability into the current force organizational construct.

The Department of Defense is challenged with balancing weapon system modernization and maintaining an operational force ready to fight and win the Global War on Terrorism. As the Department seeks to transform itself into a twenty-first century force, the acquisition process is stuck in a Cold War mentality focused on preserving the existing platform-centric approach to acquisition. Tomorrow's battlespace will be a network-centric environment derived from system-of-systems within which the sum of the parts generates an interdependent capability much more effective than the stand-alone, platform-centric environment of the past. Our DoD acquisition process is still oriented on building platforms that come to the fight as appliqué solutions, rather than seamlessly integrated warfighting systems designed to enhance the total capability. This dichotomy is straining the DoD budget by focusing our limited resources on an ever-decreasing number of platforms that are hugely expensive and fall short of meeting the ever-increasing number of capability gaps being endured by our warfighter.

This paper will examine the need to shape the DoD Acquisition Process and create an acquisition management system that is capability centered rather than platform centered. A knowledge-based process that synchronizes and optimizes capability solutions across the force is needed to ensure the warfighter needs are met within the fiscal constraints of the budgetary process. The acquisition process needs to be viewed in a more holistic manner. The various aspects of acquisition management can be viewed as layers in a system of systems acquisition architecture. A Capability Manager must be established to address all the layers of the acquisition process—not just the traditional cost, schedule and performance metrics typically

addressed by a platform Project Manager. The layers include: Standards, Requirements, Acquisition Organization, Material Solution, Material Subsystem, Operational Organization, and Battlespace.
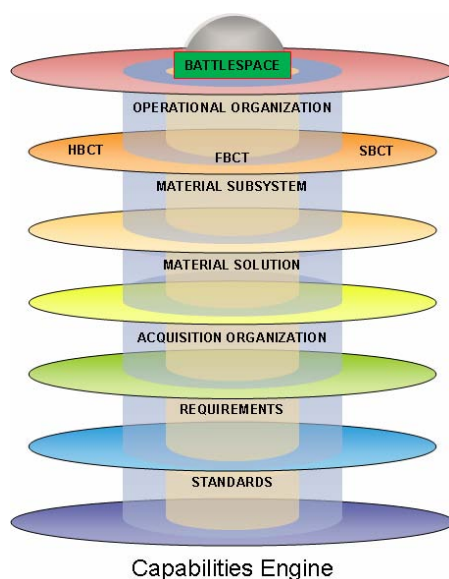
Figure 1. Material Acquisition Process Model, "Capability Engine"

These layers are interconnected in such a way that a perturbation on any layer evokes a response in all layers. By addressing capability management in a system-of-systems way, we can better align our management processes with the requirements generation process. Additionally, by inculcating a mindset that views acquisition management in a system-of-systems way that is synchronized with the capabilities-based approach to developing needs, one is better able to determine where our limited resources need to be applied—mitigating our current management approach which typically over-resources some capability at the expense of other warfighter needs.

Platform Centric Perspective

As the Department of Defense plans to invest over a trillion dollars into the acquisition process in support of new, more capable weapon systems, it is failing to address the root cause that has resulted in ever-increasing cost over runs: performance disappointments and program failures. Since 1970, the percentage of cost overrun has increased to as much as 40% or $15 billion dollars—even though there have been as many as eleven policy changes attempting to reform the DoD acquisition process. According to the GAO report, *Major Weapon Systems Continue to Experience Cost and Schedule Problems under DoD Revised Policy* (2006, April), the following table illustrates the problem facing the DoD.

Program	Percent Cost Growth	Percent Schedule Growth (months)	Percent Development Remaining
Aerial Common Sensor	45%	24	85%
Joint Strike Fighter	48%	48	78%
Expeditionary Fighting Vehicle	30%	23	60%
C-130 Avionics Modernization Program	122%	N/A	N/A
Global Hawk	166%	N/A	N/A
Future Combat System	48%	48	78%

Source: GAO. (2006, April). *Major weapon systems continue to experience cost and schedule problems under DoD revised policy*. Washington, DC: author.

As we invest more resources into fewer, more resource-intensive programs, we need to examine the root cause of the Acquisition Process's failure to gain control of its cost, schedule and performance challenges. The principle reasons often cited for cost overruns are the budgeting and requirements process; yet, this does not account for the ever-increasing dollars flowing into programs with less-than-impressive results. Additionally, the problem is not a lack of available policy and statutory guidance. Perhaps we are organized for inefficiency in that program offices are hardwired to solve material solution challenges from a singular system perspective and are not trained, organized, or resourced to leverage opportunities around them in other program offices with similar challenges.

Requirements

The battlespace, which our material solutions are supposed to support, is a highly complex, integrated environment; yet, our acquisition system continues to manage programs from a singular platform perspective without considering the relationships between all layers of the acquisition process. We often have multiple programs born from a single requirement that compete for the same scarce resources, even though these programs fundamentally provide the same capability.

We assume that the requirements process has accounted for the synchronization of capabilities, and we manage our programs from the platform perspective. No where are the total force requirements mapped against all the program of record material solutions to inform the process from a capabilities perspective. Indirectly, we create an environment that does not consider the whole more important than the subordinate parts. In an environment like this, it is impossible to manage from a capabilities perspective, since each of the Program Managers considers his/her system the ideal solution for the relatively ambiguous requirements being generated out of the DoD requirements process.

Leadership

To address the volatile, complex, uncertain, and ambiguous (VUCA) acquisition environment, the services choose the best of the best to manage our programs. We provide

them with an endless set of policies, statues, and directives and ask them to develop the best warfighting platform money can buy. Program managers are selected for their leadership and management skills to manage specific platforms or systems. Our process of selecting Program Managers reaches into our organizations and looks for individuals that are focused on getting the mission done. When we give them the mission of managing a specific platform, these same managers are programmed to succeed regardless of the program issues to their left and right boundaries. As long as their program succeeds, they are accomplishing their mission. Although our doctrine emphasizes system-of-system-level integration, we organize our program offices to look myopically at a system model rather than at system-of-systems.

Funding

Perhaps the most challenging aspect to this problem is the funding allocation. Budgets are allocated to align with specific material solutions. There is no specified Program Element in the budgeting process that recognizes the need to optimize material solutions. Consequently, Program Managers report their successes based upon a budget activity that views cost as an independent variable against schedule. Funding objectives need to support the capabilities model—which is less tangible than a hardware-focused model. The challenge is to determine the metrics by which success should be measured and how to place a dollar value on that metric.

In order to address this disconnectedness, we must change the very nature of our organizational processes and develop an acquisition process that considers the whole more important that the individual parts. Additionally, we must recognize that material acquisition is more than managing cost schedule and performance. System Program Management is a subset of capability management, which requires managing toward a collective capability and synchronizing all the relevant stakeholders from the foundation of standards to battlespace integration. It includes multiple layers that need to be synchronized for every program and balanced across the needs of the soldier and the needs of the nation as a whole.

Capability-centered Acquisition

Managing to a capability does not specify any unique material solution. Capability management strives to achieve the optimal solution across the organization—in which there may be many material solutions for a unique requirement or a single material solution for multiple platforms. The objective is to optimize the potential solution candidates that are designed to meet a requirement, ensuring the best-value solution set for the warfighter and the taxpayer.

The combined effect of multiple material or operational solutions might provide the relevant capability for the force and, subsequently, for the individual systems within the force. Figure 2 shows how multiple solutions are generated from a single requirement and blossom into multiple potential solutions based upon the individual Platform Manager's perspective. As the specified operational requirement is translated into material options, Program Managers each begin individual solution sets or material solutions with regard to their specific program. From the material solution is generated an expansive set of subsystem and software options. In today's environment, the Project Manager spends little time looking toward other Project Managers for material options, resulting in a plethora of programs designed to meet a single requirement. Ultimately, the Service has a suboptimal capability solution requiring ever-increasing time and money to support the individual material approaches derived in each program.
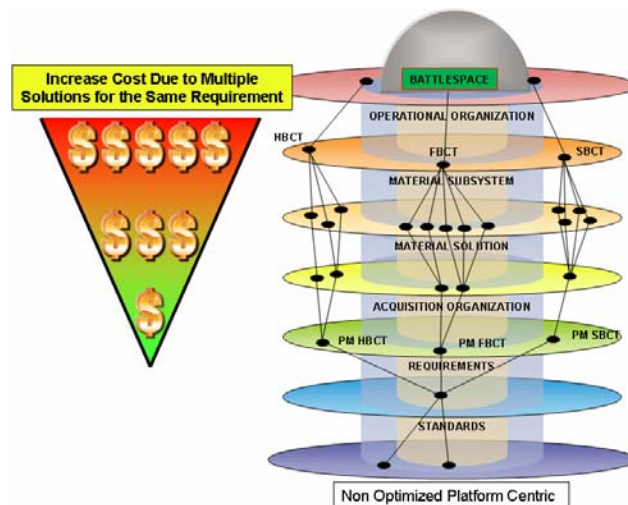
Figure 2. Acquisition Process Model "Capability Engine" Reflecting a Non-optimized Material Development Strategy

Conversely, Figure 3 depicts the same requirement being satisfied in a more optimized approach. All layers of what I refer to as the ***"Capabilities Management Engine"*** are addressed to ensure continuity in the requirement and the solution set. In order to "qualify" as an acceptable solution for a specified requirement, all layers of the "engine" must be considered and linked. The path through the engine must be optimized with the fewest number of subordinate connections. Minimizing these links requires a Capabilities Manager with the authority to influence systems horizontally across each layer of the engine with the intent on leveraging solutions sets across multiple programs.
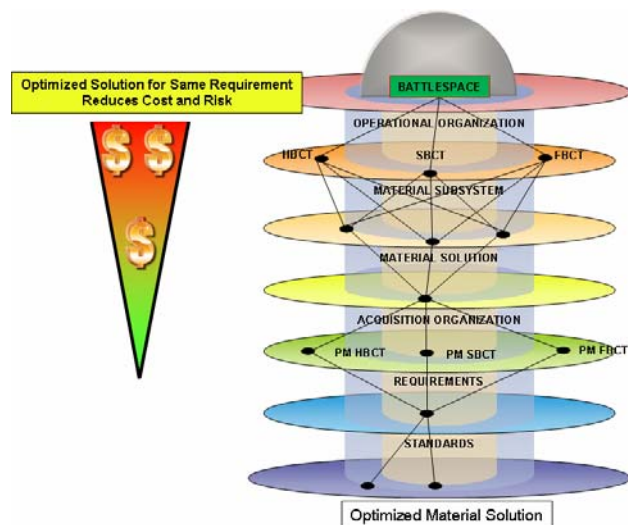
Figure 3. Acquisition Process Model "Capability Engine" Showing an Optimized Material Development Strategy Solution

Capabilities Engine:

The synchronizing process is the key to being able to ensure success in the capabilities-centered acquisition environment. The "Capabilities Engine" needs to consider all aspects of

the requirement, material, organizational, and policy environment and be able to synchronize this across multiple programs.

- Capability Layer 1 (CL1): Standards. The standards layer is the foundation upon which all acquisition programs are based. Standards encompass policy, statute, regulations, treaties, etc. All programs must be tied back to firm standards foundations lest they be developed in contravention to the authoritative documents upon which our institutions are formed. This may seem obvious, but it is a critical step that is often not well understood by Program Managers.

- Capability Layer 2 (CL2): Requirements. The requirements process is the beginning of all programs. The warfighter determines a unique need and validates the need must be satisfied with a material solution. Simply levying a requirement, however, is insufficient. All of the intended and unintended impacts of requirements must be completely vetted with regard to the systems that are already fielded and those in the development process. The Capability Manager will link the requirement to the appropriate program offices, the material solution and its subsequent subsystem contributors and ultimately back to the warfighter. The intent is to establish a clear path with an optimized solution from requirement inception to retirement.

- Capability Layer 3 (CL3): Acquisition Organization. This is simply the acquisition organization that is most appropriate to develop a specific material solution for a requirement. Often, a single requirement will be levied upon multiple program offices. Without a Capability Manager to synchronize the respective program offices, the risk remain that singular solutions will be developed for individual platforms.

- Capability Layer 4 (CL4): Material Solution. As material solutions are developed, the Capability Manager will match similar solutions and optimize the set to minimize the total capital outlay necessary to meet the specific requirement. This is the point at which the Program Managers must share resources in order to minimize the total cost and ensure a synchronized capability is maintained to meet the common requirement. Throughout this synchronization process, however, each Program Manager must develop a solution that is consistent with his/her platform-strategic plans. This, in fact, is how the Program Manager is chartered and funded. It is the Capability Manager's mission to ensure the overall solution is optimized across the organizations.

- Capability Layer 5 (CL5): Material Subsystem. CL5 is similar to CL4 with the exception that the total number of potential solutions is orders of magnitude greater. Here is where the "good idea" cost driver is most apparent. The multitude of subcomponents for a system are ripe picking; any vendor, government organization, or anyone with a good idea to solve an engineering problem will use whatever means necessary to convince a Program Manager to resource their project. Left unchecked, this is where programs run the greatest risk of being desynchronized with each other. Additionally, this is where programs tend to allow "requirements creep" and contribute to increasing program costs. The Capabilities Manager must synchronize subsystems between program offices and ensure they are consistent with each of the subordinate layers. Failure in this area manifests itself as inefficient, redundant, or worse: incompatible systems on the battlefield.

- Capability Layer 6 (CL6): Operational Organization. The operational test community and the user must look at the combined nature of the material solutions and assess whether or not the material solution is simply a slightly better appliqué of what already exists. The user must hold the acquisition community accountable for developing

system-of-system solutions that are mutually supporting and as common between systems as possible.

- Capability Layer 7 (CL7): Battlespace. The battlespace is the future state at which a particular service views its warfighting posture. All systems must support this objective. Lack of a clear link to the future state might reveal program flaws or non relevance to the objectives of the National Military Strategy and subordinate service objectives.

As a requirement is developed, a clear link from CL1 through CL7 must be established and managed. The Capability Manager can synchronize the seven layers for specific platform solutions across multiple program offices. Platform Program Managers manage their programs horizontally, with respect to time and program milestones. The Capability Manager manages "vertically" within each phase of the spectrum of Programs attempting to optimize the material solution across multiple platforms and through the seven layers of the capability engine.

Knowledge-based Decisions

Managing from a capability-centered perspective is significantly more complex than the traditional platform-focused approach. One must account for all aspects of the organization and be willing to accept being dependent upon the success of other organizations and managers. This is inherently counterintuitive for the "traditional" Project Manager, in that the "success at all cost" approach to doing business is significantly dependent on others outside of the Program Manager's sphere of influence. Consequently, managing toward an optimized capability is highly dependent on having a well-established knowledge-based process, a clearly defined execution strategy, and well-defined roles and responsibilities. Additionally, leadership at least two levels up must emphasize and support an organizational structure that facilitates the seamless execution of the capabilities model.

A knowledge-based capability model will enable developers to be reasonably certain at critical junctures, or "knowledge points" in the acquisition lifecycle, that their products are more likely to meet the cost, schedule, and performance baselines of the individual contributions of each project office and provide an optimized solution set which meets both the warfighter requirement and mitigates redundancy and excessive resource demand.

Knowledge-based capabilities management requires that someone manages the knowledge process and has the authority to influence the platform-centered processes. As the operational commander's weakest point on the battlefield is at the seams (the boundaries between units), the acquisition Project Manager's weakest point is the relationship between his program and that of another Project manager. This is the where the Capabilities Manager, using a knowledge-based process will strengthen the overall capability solution. Figure 4 represents key points at which the Capabilities Manager should influence the processes of the platform-centered Project Manager.
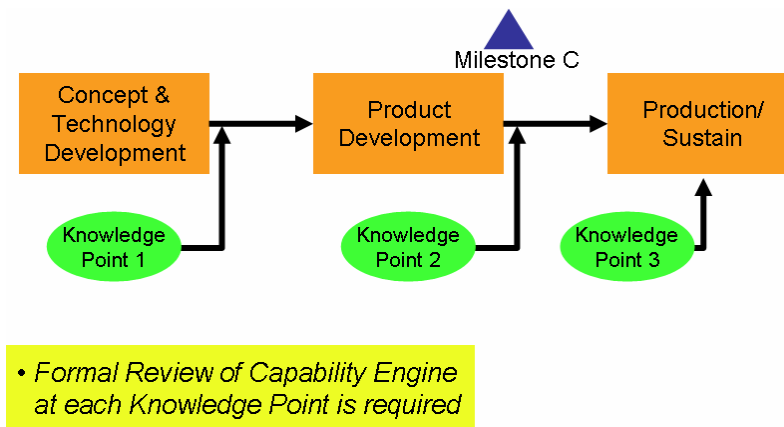
Figure 4. Knowledge Points at Which Capability Manager Validates Optimization of Material Solution for a Specified Program

The Capabilities Manager will synchronize all seven layers of the "Capabilities Engine" at each of the three knowledge points of the Platform Project Manager. The platform-centered Project Manager manages across time with regard to the five phases of the acquisition lifecycle. Those phases include the: Concept Refinement, Technology Development, System Development and Demonstration, Production and Deployment, and Operations and Support phases. At each phase, the Project Manager strives to attain the best-value solution for a specific requirement for his/her platform. If multiple Platform Managers have similar requirements, these Platform Managers will focus on obtaining best value for their platforms within the constraints of their resources and where they are in their respective lifecycle phases.

By managing the seven layers of the Capabilities Engine, the Capability Manager looks vertically at specific knowledge points in time to ensure that all potential solution sets are considered across multiple platforms. Formal synchronization points at which the Capability Manager reports success against a specified set of metrics (cost, schedule, and performance perspective) can be achieved across multiple programs. The Knowledge Points suggested in this paper are consistent with those recommended by the GAO study that reviewed the NASA process with which it made its investment decisions (GAO. (2005, December). *Implementing a knowledge-based acquisition framework could lead to better investment decisions and project outcomes.* Report to Congress. Washington, DC: author).

- Knowledge point 1 (KP1): Resources and needs match. Knowledge point 1 occurs when a sound business case is made for the product. According to the GAO, this requires a match between the customer's requirements and the product developer's available resources in terms of knowledge, time, workforce, and money. By synchronizing all seven layers of the Capabilities Engine at this point, the Capabilities manager not only matches requirements with resources and time, but ensures the requirement is consistent with standards, an optimized material solution, is appropriate for the specific organization receiving the system, and, most importantly, is consistent with the battle space within which the material solution will be integrated.

- Knowledge Point 2 (KP2): Product design is stable. Design stability is critical to reducing risk. At this point, the Capability Manager continues to validate that all the layers of the Capability Engine are synchronized and that no perturbations from any of the layers has caused a break in the connection from the Standards layer to the Battlespace layer. Additionally, the Capabilities Manager ensures that the solution(s) for

the initiating requirement are still consistent with the warfighter's intent and that the Platform Managers have not introduced potential dissimilarities within their platform-strategic plans than might manifest in subsequent phases.

- Knowledge Point 3 (KP3): Production Processes are mature. This is effectively the Platform Manager's milestone C point at which the risk must be low enough to precede into production contracting. The Capabilities Manager has less of a role at this point—with the exception of continuing to monitor the capability effects across the layers of the Capability Engine. Configuration management of the platform solution is critical to maintaining a consistent capability across the force. At this point, if the Platform Manager introduces changes to the production architecture, the potential exists for the synchronized solution to "stovepipe" into a unique platform solution. The Capability Manager must monitor the configuration control of all systems across multiple Program Offices, with regard to each other, while the Program Manager must continue to sustain and improve the capability on the unique platform.

Conclusion

Viewing material acquisition in a more holistic manner and striving to optimize solutions for specified requirements should be the goal for all the Services. Although the defense budget is low with regard to the GDP compared to past points in history, current-year dollar value is the highest it's ever been. The acquisition process, however, continues to develop fewer systems at greater expense. As the warfighter views the battlespace as an interconnected environment of mutually supporting systems, our Program Management process must also adapt to this environment. We must begin to view systems as contributors of capability in which systems are mutually supporting, in which the combined effect is greater that the individual parts. A Capability Management Process that supports the "traditional" Program Management process needs to be developed to inculcate a standardized approach to managing capability.

The thoughts presented in this paper look at the need to change the current paradigm and how one might approach a capability management model. The problem is complex, but the need for a solution is imperative. Developing an execution strategy to capability management is even more complex. Understanding the need to optimize and synchronize material solutions is merely the beginning. Developing an organizational construct to execute this mission is worthy of continued study and, ultimately, of implementation. It is important in this study to heed the words of Sun Tzu: "avail yourself also of any helpful circumstances over and beyond the ordinary rules"; for as in War, the systems we provide the warfighter will shape the outcome of the battle.

Lessons from Army System Developments

Presenter: William (Bill) A. Lucas is Executive Director of the Cambridge-MIT Institute (CMI)—a partnership between MIT and Cambridge University funded by the UK government—where he holds an appointment as Principal Research Scientist. He began as Executive Director of the International Center for Research on the Management of Technology, Sloan School of Management in 1996, and then joined CMI in 2000, serving initially as its Deputy Director with particular responsibility for program delivery and assessment. He was concurrently Co-Director of the Centre for Competitiveness and Innovation in the Judge Business School at Cambridge University. His career includes university teaching and research at State University of New York at Buffalo and a year as Visiting Professor of Public Administration at the George Washington University, six years as a Senior Social Scientist at The Rand Corporation, and government service as Associate Administrator of the US National Telecommunications and Information Administration. His research includes the study of knowledge exchange in cross-functional development teams in industry and in university-industry collaborations, and investigation into the development of young professionals who will become leaders of innovation either in the firm or in start-up companies. He teaches innovation processes and methods of applied social research.

Presenter: Richard (Dick) G. Rhoades is Director of the University of Alabama in Huntsville's (UAH) Research Institute and Professor of Engineering Management. He has ongoing research activities funded by a variety of organizations, including the Army Space and Missile Defense Command, the Army Aviation and Missile Command, the Army Aviation and Missile Research Development and Engineering Center, Aerojet General Corporation, Colsa Corporation, and L3-SY Coleman. His work focuses on weapon system technical risk assessment and avoidance, propulsion system design analysis, strategic planning and organizational design. He serves on a number of weapon systems independent assessment ("Graybeard") panels and provides a continuing assessment of technical and programmatic risk, together with recommended mitigation approaches, to the Directors of these programs. Prior to joining UAH, Dr. Rhoades held numerous positions in the Missile Research, Development and Engineering Center at Redstone Arsenal, including three Senior Executive Service positions: Director for Propulsion, Associate Director for Technology, and the Associate Director for Systems.

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Abstract

This paper documents the results of a multi-year Army Materiel Command-sponsored research project which employed a structured case study approach to examine the history and processes that had resulted in the introduction of a number of technology-based Army systems in time to make a positive contribution to the outcome of Desert Storm. In addition to the fifteen case studies documenting these programs, a common set of data was obtained for each system studied. These data were analyzed to identify factors contributing to successful systems development; this paper contains the results of this analysis.

Several of the statistically significant relationships found involve factors that are related to the stability of the program. When key members of the project team left the program too early, project outcome suffered. Further, both project funding cutbacks and project team turn-over negatively correlated with the quality of the testing program and the timeliness of key test events. These two attributes of the testing program also had the strongest correlation with project outcomes. In addition, changes in systems requirements during development correlated with poor project cost performance. Finally, turn-over in key user-representative personnel correlated negatively with system performance in the field. A central conclusion from this study is that shorter development cycle-times favorably correlate with key project outcome variables, largely by minimizing the exposure of the project to destabilizing influences which were also shown to correlate negatively with these same outcome variables.

Keywords: technology-based Army systems, project outcome, system requirements, development cycle-time

Introduction

This paper documents the results of a research project of several years' duration which employed a structured case study approach to examine the history and processes that had resulted in the introduction of a number of technology-based Army systems in time to make a positive contribution to the outcome of Desert Storm. The 15 case studies that resulted were developed on systems ranging from the M829A1 "silver bullet" to the GUARDRAIL Common Sensor and the APACHE attack helicopter.

Research Project Information

- Principal Sponsor: Army Material Command
- Principal Investigators: Bill Lucas (MIT) and Dick Rhoades (UAH)
- Research Period: September 1999 to May 2004 (data analysis and report preparation continued into 2005)
- Funding: ~$200,000
- Research Purpose: Examine the history and processes used in the development of a number of Army systems which made a positive contribution on the battlefield during Desert Storm
    --determine factors which influence success
    --prepare case studies

Figure 1. Project Overview

Systems Studied

System	Researcher	Commodity category
APACHE attack helicopter	Ference	Aviation
TADS/PNVS (target acquisition and designation/pilot's night vision systems)	Oelrich	Aviation
MLRS rocket system	Sherman	Missiles
ATACMS missile system	Romanczuk	Missiles
M40 chemical protective mask	Ruocco	Soldier support
Dismounted microclimate cooler **Note: Did not enter production**	Ruocco	Soldier support
Mounted microclimate cooler	Ruocco	Soldier support
M829-A1 armor–piercing kinetic energy tank ammunition	Mitchell	Ammunition
FOG-M (fiber optic guided missile) **Note: Did not enter production**	Sherman	Missiles
TOW-2A (Tube-launched missile)	Vessels	Missiles
AN/TAS 4 infrared night sight	Granone	Target acquisition
Joint Stars Ground Station	Sherman	Intelligence
Guardrail common sensor	Sherman	Intelligence
PAC-2 (PATRIOT anti-missile system)	Sherman	Missiles
HELLFIRE missile system	Johansen	Missiles

Figure 2. Systems Studied

The case studies were developed through the use of structured interviews with key participants from the government/contractor team that developed each system. In addition to the case studies, this process resulted in collection of a common set of data for the systems studied which could then be analyzed to identify factors contributing to successful system development. The results of this analysis are contained in this paper. Two of the 15 case studies examined systems which might have been useful on the battlefield (based on the views of Army technical leaders), but that failed to successfully complete development. The intent of including failures in the research was to provide a basis for distinguishing factors which contributed to both successful and unsuccessful system developments. While they are useful for the qualitative lessons they offer, two cases are inadequate for quantitative analysis; most analysis focuses on the 13 successful cases. The study is, therefore, primarily an assessment of contributors to the relative degree of success.[5]

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[5] The LeanTEC project was a four-year study of the development and transition of technology-dependent systems in the aerospace industry, supported by a cooperative research agreement between the US Air Force Manufacturing Technology Office and The Boeing Company.

Research Methodology

- Army RDEC and PM leadership nominated systems which either did or could have impacted Desert Storm
- Researchers (intended to be "free" Army student labor) selected a system from list of candidates
- "Structured thesis" approach used to gather comparable data on each system studied, but allow researcher to document areas of particular interest in each case study
- Modified version of questionnaire used on LeanTEC* was administered to Army and contractor development team members; researcher integrated responses
  ---produced composite "best answer" questionnaire
  ---produced case study on system development

15 systems, 13 produced dictated a focus on relative success factors

Figure 3. Methodology Employed

The heart of any systematic study is the definition of a common outcome measure that allows comparison. The obvious path was to compare the projects and systems based on their performance relative to their agreed-upon goals and requirements. Each project had a budget, a systems procurement cost goal, a set of technical requirements, and completion dates. In addition, three questions of performance are immediately observable and easily remembered by project managers: Did the system go into production? Once production was started, were problems found that required that further engineering changes be made? And did the system perform well in its use in Desert Storm? Structured questions were used to ask the key government and industry interviewees about how well their projects performed in these areas, with a range of answers that characterized how badly the projects had missed meeting their objectives if they had not been completely successful. Each of these outcomes is shown graphically in the histograms which follow.
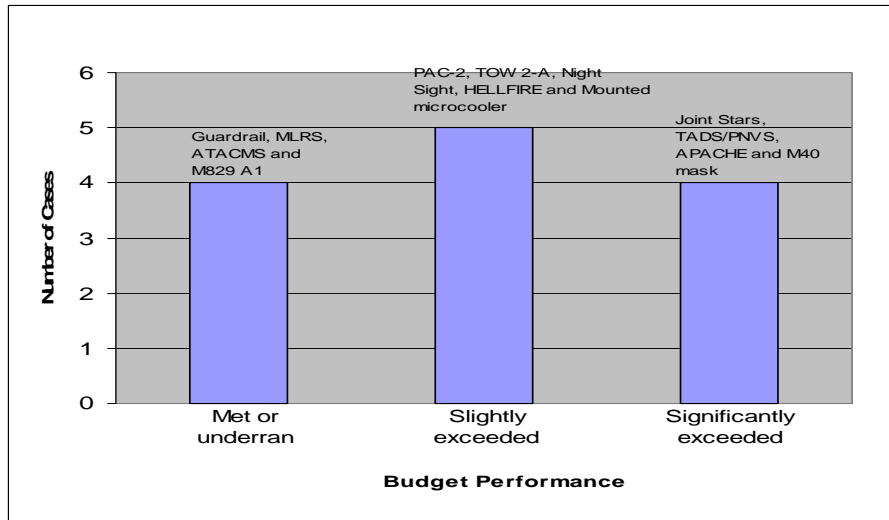
Outcomes-Development Budget

Figure 4. Development Budget
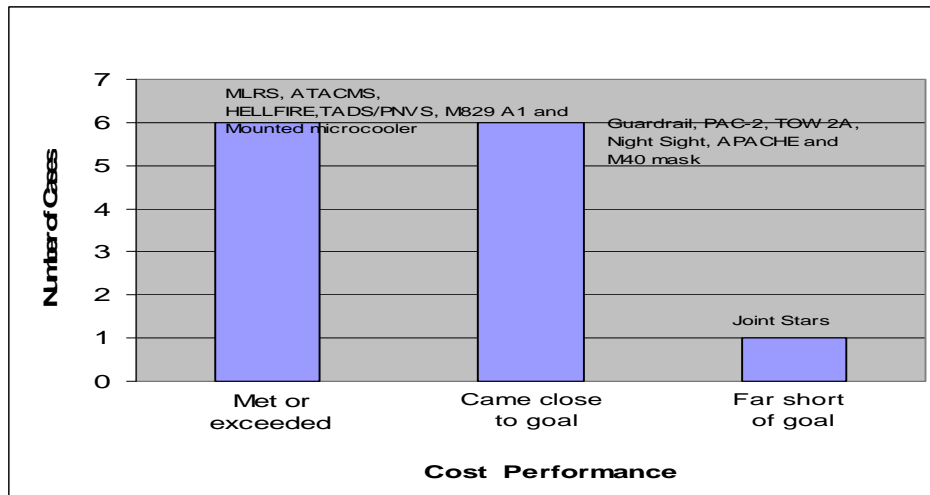
Outcomes-System unit cost

Figure 5. System Unit Cost
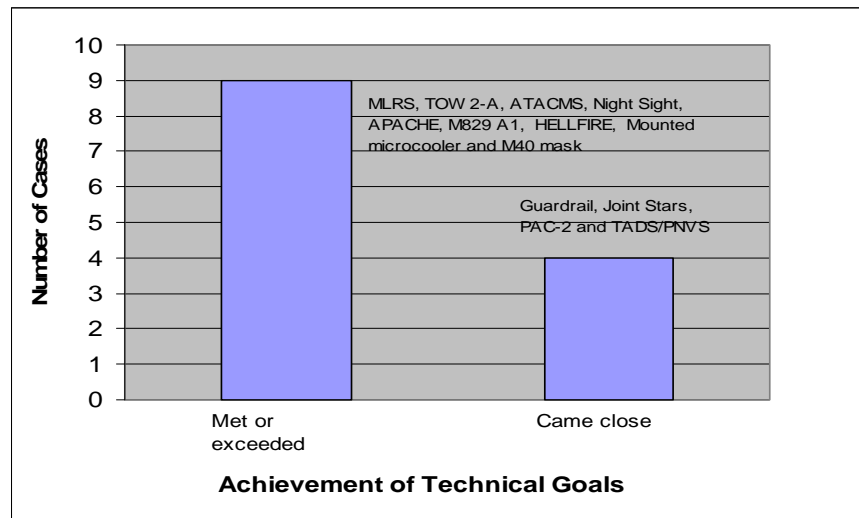
Outcomes-Technical performance

Figure 6. Technical Performance

Outcomes-Delay in transitioning to production
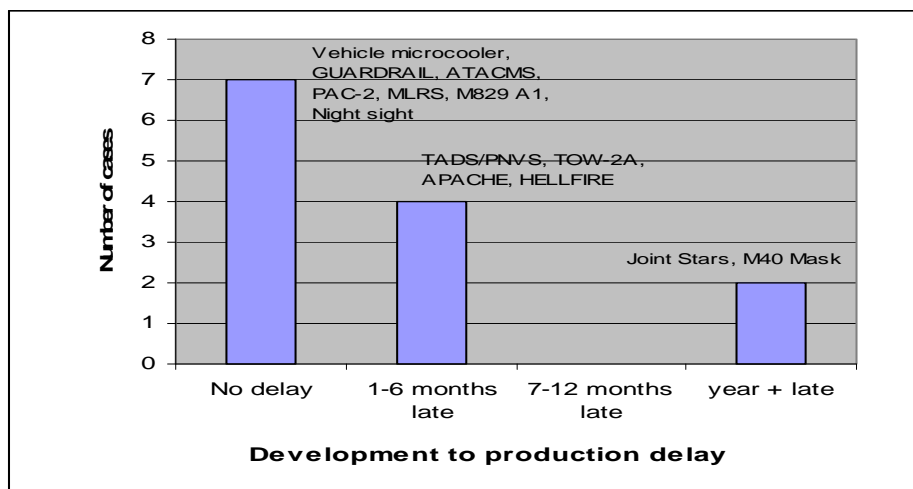
Figure 7. Delay in Transitioning to Production

Outcomes-Changes in production
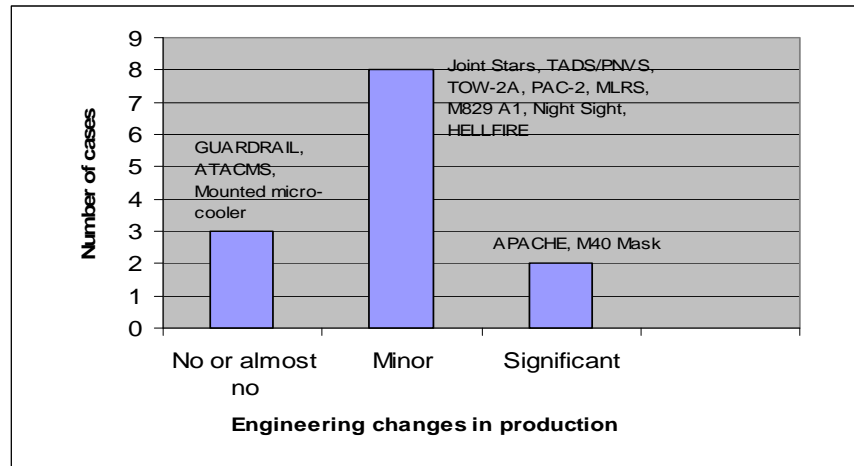
Figure 8. Changes in Production

Six of the outcome measures mentioned above were used to create a scale that scores the (system) projects from zero to six according to the number of key outcomes a project achieved. If a project was (1) transitioned to production on time, (2) developed within budget, (3) had no late engineering changes, met both (4) the goals for system unit costs and (5) its technical requirements, and encountered (6) no difficulties when it was deployed in the field, it was awarded (the maximum) six points.

Outcomes-Integrated Scale
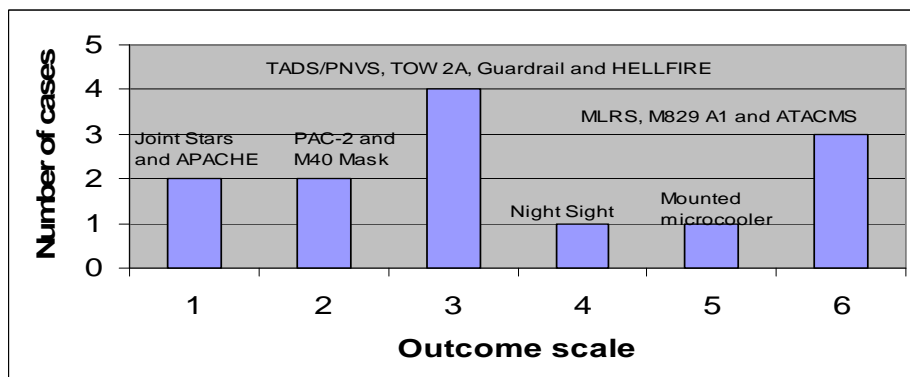
Scale: Sum of number of preferred outcomes using six outcome metrics

Figure 9. Integrated Scale

Table 1 (next page) contains summary information on the 15 systems studied. For each system, this table also contains information on the duration of the development phase of the program and a summary of the project manager's description of the most difficult problem encountered. It is interesting to note that lack of sustained user support for the requirement the system was intended to satisfy was mentioned as the most difficult problem for the two failures, but user-related issues were not identified for any of the successful development cases.

System/case	Development duration (months)	PM's most difficult problem	Key outcomes achieved (0-6)
APACHE attack helicopter	108	Control of production costs; influenced by integration plant location choices	1
TADS/PNVS (target acquisition and designation/pilot's night vision systems)	~36	Cost growth in development	3
MLRS rocket system	33	Establishing and managing four-nation cooperative development program	6
ATACMS missile system	37	Key vendor went out of business	6
M40 chemical protective mask	~48	Immaturity of critical technologies	2
Dismounted microclimate cooler **Note: Did not enter full development**	Not applicable	Lack of stable user requirements due to immaturity of technology	Not applicable
Mounted microclimate cooler	~24	Key vendor failed to support integration schedule	5
M829-A1 armor–piercing kinetic-energy tank ammunition	~36	Achieving needed innovation in system design	6
FOG-M (fiber-optic guided missile) **Note: Did not complete development**	Not applicable;	Lack of sustained user support	Not applicable
TOW-2A (Tube-launched missile)	48	Stability of threat armor requirements	3
AN/TAS 4 infrared night sight	~24	Selection of unqualified vendor and split management responsibility	4

Joint Stars Ground Station	105	Cost and schedule growth/delivering complex software	1
Guardrail common sensor	~24	Complexity of integration of mission equipment	3
PAC-2 (PATRIOT anti-missile system)	~52	Early fielding to meet SCUD missile threat	2
HELLFIRE missile system	~84	Adversarial relationship between key vendor and prime	3

Table 1. Summary Case Information

Standard statistical analysis procedures appropriate for this number of cases and type of data were used to identify and evaluate correlations between the factors studied and the several outcome variables, and, in some cases, among the factors. The results of these analyses are summarized in Table 2. The testing/simulation and technological maturity factors were included because of their identification in recent Government Accounting Office studies as key determinants of success.

Factor	Relationships Found/Comments
1. Project team characteristics and practices:	
—leadership	Team leader's perceived ability to obtain resources, his/her breadth of experience and ability to resolve technical issues all are positively related to reduced engineering changes during production and to completing development within budget.
—staffing	Low turnover in key project team members relates positively to completing development within budget, to meeting system unit cost targets and to achieving system performance objectives.
2. Role of government S&T organizations	Army labs/centers were typically actively involved in both pre-development and development phases, actively involved in both successes and failures, and actively involved in both short and long developments.
3. Testing and simulation approach	Validating component and system maturity at the right time in the program relates positively to completing development within budget, to meeting system unit cost targets and to successful performance in the field. The quality of the testing and simulation conducted relates positively to reduced engineering changes during production and to meeting system unit cost targets.
4. Importance of stability:	
—funding	Funding uncertainty was related to increased turnover in key project team members and the need to deal with changes in testing plans and other project structure issues.
—system requirements	Changes in system requirements, particularly during the middle of development, relate to an increase in late engineering changes and negatively to project success in meeting its goals for systems costs.
—key user (TRADOC)	Changes in key TRADOC personnel during development

personnel	relates to less successful performance in the field.
5. Timely communication of problems	Nearly all cases described timely communication of problems from contractor to government PM and from government PM to Army leadership.
6. Importance of technology maturity (TRLs)	Maturity of critical technologies used in systems studied, as measured by TRLs, was similar to that found in previous LeanTec study of small electronics projects. No positive correlation found between higher TRLs at the start of development and most outcome variables.

Table 2. Summary of significant relationships

Several of the statistically significant relationships involve factors that are related to the stability of the program. When key members of the project team left the program too early, project outcome suffered. Further, both project funding cutbacks and project team turn-over negatively correlated with the quality of the testing program and the timeliness of key test events. These two attributes of the testing program also had the strongest correlation with project outcomes. In addition, changes in systems requirements during development correlated with poor project cost performance. Finally, turn-over in key user-representative personnel correlated negatively with system performance in the field.

Destabilizing Influences

Variable	Timing Implications
1. Reductions in project funding	Potential for change in administration every 48 months; typical turn-over in key military leaders occurs every 24-36 months. Potential change in key Congress positions every 24 months; likelihood increases with development duration
2. Uncertainty in project funding	Potential for change in administration every 48 months; typical turn-over in key military leaders occurs every 24-36 months. . Potential change in key Congress positions every 24 months; likelihood increases with development duration.
3. Change in system requirements	Changes in the threat environment occur unpredictably, but become more likely with longer development durations. Changes in doctrine and system requirements follow a similar pattern.
4. Change in key user representatives	Typical turn-over in such key military positions occurs every ~36 months
5. Change in key project team members	Typical turn-over in military acquisition positions occurs every ~36 months. Longer development durations present more opportunities for career moves on the part of key civilian team members

Figure 10. Destabilizing Influences

Taken together, these several relationships strongly suggest that stability of program resources and objectives is a very powerful influence on the relative success of the project. In reflecting on this array of instabilities that could impact a system development, it became clear that they had at least one thing in common: The longer a system stayed in development, the greater chance it had to experience one or more of these program destabilizing events. Or, stated another way, shorter system development cycles should result in better project outcomes. When this hypothesis was tested by examining the correlation between the system development durations and the aggregate outcome scale (See the data in Table 1), a strong correlation was found. A central conclusion from this study is, therefore, that shorter

development cycle-times favorably correlate with key project outcome variables—largely by minimizing the exposure of the project to destabilizing influences which have also been shown to correlate negatively with these same outcome variables.

Central Conclusion

Shorter development cycle times favorably correlate with key project outcome variables, largely by minimizing the exposure of the project to destabilizing influences

Length of Project Development and Project Performance (Average number of successful outcomes)			
	Over 3 years	Three years or less	Sig. at
Length of development	2.00	4.71	.002

Figure 11. Conclusion

Whether or not a change to selecting projects with shorter development times is made, the Army could do more to stabilize the guidance and resources given to both shorter and longer development projects. Acting alone, the Army could do more to map rotating personnel assignments and other sources of TRADOC change to project development cycles. Since it appears, as is widely believed, that changes in systems requirements made once projects move beyond early development will almost certainly hurt project performance, the Army could eliminate all but the most critically important of such changes. Both through contract language and informal management practices, the Army could work with its contractors to provide better continuity of development project staffing.

The defense acquisition community has long recognized that lengthy systems development times are disadvantageous. Sometimes the associated negatives have been phrased in program instability terms; this study certainly provides strong empirical support for those who hold these beliefs. Over the years, a number of initiatives have been attempted to shorten development cycles, with limited success where complex systems were involved. The current approach is referred to as "spiral development"; its basic concept is to get a useful, if limited, capability in the field quickly and then introduce additional technology-based capabilities through further "spirals" of development. This approach appears to be in keeping with the implications of this study's central conclusion.

Too Little Too Soon? Modeling the Risks of Spiral Development

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Abstract

The DoD's evolutionary acquisition policy is directed against project risk, but bears inherent risks of its own. The DoD policy for evolutionary acquisition mandates multiple product releases via spiral (i.e., amorphous & unplanned) or incremental (i.e., defined & deferred) development methodologies for all programs. All amorphous spirals eventually become definitive increments. Incremental development entails the deliberate deferral of work to a subsequent phase. Computational organizational modeling using systems dynamics reveals that this methodology introduces more concurrency during development, and more variety in production. The result is earlier delivery of the first increment, but with later and more costly

delivery of subsequent increments than if conducted via a single-step methodology. Curtailments of scope by the exclusive use of mature technology enable more effective delivery of the first increment, further illustrated by two case studies. Duplication, rework, transaction costs, decision backlog and error are causes of inefficiency in the successive increments. Production variety and mixed configurations produce obvious implications for logistical supportability, training, failure causality, compatibility and interoperability, etc. Further, certain attributes of hardware products might help determine the suitability of this development methodology. Products that are nearly immutable, which have binary requirements for key capabilities, require man-rating, or are maintenance-intensive may not be good candidates for incremental development. Mutable products with costless production, continuous requirements, low maintenance, or time criticality are more likely to reap advantages from this development approach. While modular open systems architecture facilitates system adaptation, modularity itself does not necessarily create evolutionary advantages due to relative modular interdependency. Program managers must be aware of the inherent risks of these agile acquisition methods and take additional steps to balance them with appropriate planning and resources, disciplined change-control measures, organizational accommodations and accountability for configuration management.

Keywords: Evolutionary acquisition, spiral development, incremental product development, Javelin, ATACMS, agile development methodologies, computational organizational modeling, modularity.

Introduction—The Inevitability of Change

We are told in Diogenes Laertius's *Lives and Opinions of Eminent Philosophers* (early 3rd century) that the Greek philosopher Heraclitus (c.535 - 475 BC) was the first to observe and say, "Everything flows; nothing stands still,"—the popular derivation of which is, "The only constant is change." Indeed, everything does seem to change, evolve and give rise to variety in the world. Since his work in the 1830s, Charles Darwin receives much of the credit for furthering a theory of biological evolution. While not the first to have the idea, he associated observations of species *variety* on the island of Galapagos with species *environment*, and suggested that nature selected the variations that were the fittest (Darwin, 1859). In its time (and even since), the idea was considered radical and a threat to the religious and social order of things. Mere variety itself can be controversial, since, paradoxically, variety is appreciated in some domains (see the writings of William Cowper, 1731-1800)[6] and abhorred in others (Neave, 2000, March 2).[7] At the core of the subject of evolutionary acquisition are ideas and phenomena about variety and change. As a policy for system development, it is controversial too. As with Darwinian concepts, product evolution involves *information* transfer, interaction with the *environment* and unpredictability of change outcomes. But unlike evolutionary biology, product variations and selections occur frequently and are non-random. Program managers typically seek stability—in program requirements, in funding, in system design, and in production configuration. But it seems the only constant is change. Everything changes and evolves over

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[6] See also: Kerr (1979, p. 65) about the basic human need for variety and complexity. Ashby's Law of Requisite Variety states that the internal regulatory mechanisms of a system must be as diverse as its environment in order to cope with the variety of challenges imposed by it (Ashby, 1960).

[2] "Variation is nasty: it makes things difficult, unpredictable, untrustworthy: bad quality." "In a big way, bad quality means too much variation, good quality means little variation."

time. Much of what the authors have found in their following research on spiral development and project management is about how managers must cope with product variety and change. Using case study analyses, review of current subject literature, and computational modeling, the focus of our research was to ascertain the acquisition management implications of spiral development, obtain lessons learned in past programs as applicable to future development efforts, model and simulate projects using different acquisition approaches, derive predictions and make recommendations to project managers for the effective and efficient harnessing and implementation of spiral development.

Background

Projects have long been defined as *unique* and *temporary* enterprises, as opposed to common and ongoing operations. The latest (2004) version of the *Project Management Body of Knowledge* (*PMBOK*) increased its emphasis upon the term "*progressive elaboration*" to describe a third fundamental characteristic of all projects. It means, "developing in steps and continuing by increments; worked out with care and detail; developed thoroughly" (*PMBOK*, 2000; *PMBOK*, 2004, p. 6). This term relates to project uncertainty and describes the eventual realization of project scope only after multiple iterations of planning. The *PMBOK* asserts that progressive elaboration is both a necessary *characteristic* of projects (occurring throughout their lifecycles), as well as a *technique* for development of product specifications. It is accomplished via the learning that takes place over time as project ambiguity resolves, so that project scope becomes more explicit and detailed (as opposed to "requirements creep," which is considered uncontrolled change). The *PMBOK* later asserts that change in the course of projects and products is inevitable, and mandates the need for a *disciplined change-control process* to control its impacts—from inception to completion (*PMBOK*, 2004, p. 119).

There are many new DoD terms for project management and product development methods. DoD promulgated *evolutionary acquisition* (EA) as policy in 2000, and soon after, *spiral development* for the preferred acquisition strategy of all materiel. EA's goal is to phase requirements and provide capability sooner. But there has been confusion over terms, despite further elaboration and even codification in statute, and it still persists today, along with a lack of full understanding of many policy implications—especially some inherent risks. *EA operationally means there will always be multiple product releases of an item.*

The policy thrust is primarily about the reduction of product cycle-time within an uncertain environment, by exclusively using mature technology. The DoD's requirements process has also followed with "evolutionary" requirements documents—a new idea. Uncertainty is the usual realm of program managers, especially in defense systems, and is usually dealt with by seeking best information. Earlier reform initiatives were aimed at overcoming information gaps and technology lag. The 1990's Integrated Product and Process Development (IPPD) initiative was about gaining collective wisdom for early and complete requirements realization. As concerns over DoD acquisition program costs and cycle-times continue in the current mid-2000s era, the DoD has not abandoned the use of IPPD. But by embracing evolutionary requirements and acquisition, it has acknowledged that information will never be complete, either from stakeholders or with regard to ever-changing technology. It now implicitly concedes that developers will learn about their design over time ("requirements realization"), and users will accretively gain knowledge about how they can better use the new

capability ("product discovery").[8] Thus, a major paradigm shift for product development has occurred in the DoD: *from a collaborative quest to capture and address all requirements early on, to an allowance of eventual requirements discovery with full attainment only after visualization, feedback and environmental changes occur along the way*.

The Enabler: Mature Technology Reduces Risk

This is not to say, however, that the DoD has in its policy embraced technological uncertainty for the commencement of advanced development. Quite the contrary—for at the very heart of the evolutionary acquisition strategy is the requirement for the exclusive use of mature technology to reduce technology risk. The impetus for this undoubtedly lies in the body of work by the Government Accountability Office (GAO) over the last ten years,[9] which has obviously and greatly influenced the *DoD 5000* series. The GAO encourages the use of knowledge-based processes and specifically separates technology development from product development. It argues that shorter product cycle-times are the hallmark of program success and, therefore, should be limited to five years for more frequent introduction of new technologies into weapon systems, speeding them to the warfighter. We note that this is not much longer than the average development time for a new model of automobile—typically 3-4 years—which occurs in a very mature and cyclical industry (Kim, 2002, June). The GAO's target may ignore the significantly greater amount of technology development required in many DoD projects compared with most automobile development projects.

Most emphasized by the GAO (in the many reports reviewed by these authors) is the aspect of technology maturity before commencement of advanced development. The Office applies a 1-through-9 rating scale of *technology readiness levels* (TRL) that was developed by the National Aeronautics and Space Administration, adopted by Army and Air Force research laboratories, and recently implemented in the *DoD 5000* series (in particular, the *Defense Acquisition Guidebook*—formerly *DoD 5000.2R*). Until recently, the DoD had no specific requirements for use of TRLs, but levels 6 and 7 now satisfy its guidelines for technology maturity at Milestone B. TRL 6 states that the technology has been demonstrated in a *relevant* environment (simulating the key aspects of the operational environment), and TRL 7 is its demonstration in an *operational* environment (that which addresses all operational requirements and specifications required of the final system, to include platform/packaging). The GAO clearly prefers TRL 7 as the level of technology maturity that will represent a low and satisfactory risk for starting product development (GAO, 2005, November 15). The Office acknowledges that users may not initially receive the *ultimate* capability under this approach, but that the initial capability will arrive predictably *sooner and cheaper* (GAO, 2005, November 15).

In some respects, developing only mature technology as a fundamental program requirement is similar to an earlier attempt to constrain project scope. Cost as an Independent

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[8] The authors' terminology for what has so often been observed from their experiences. Most of us have long known that full realization of requirements and visualization of the product often takes multiple iterations of design, with feedback loops from modeling and testing activities. And sometimes the customer doesn't fully realize what can be done with the product until it is in hand. We call that *product discovery*, and the authors can cite several examples of this in both commercial and defense applications (i.e., cell phones as improvised explosive device triggers, etc.).

[9] See in particular: GAO/NSIAD-98-56; GAO/T-NSIAD-98-123; GAO/NSIAD-99-162; GAO/T-NSIAD-99-116; GAO/T-NSIAD-00-137; GAO-01-288; GAO-02-701; GAO-03-57; GAO-04-53.

Variable (CAIV) was an acquisition reform initiative that emerged in 1995 as a means of trading scope, or system performance, to achieve cost objectives. It was one of very few initiatives that were oriented on *what*, not *how* (i.e., processes) the DoD acquires its materiel.[10] To date, its actual savings benefit has been difficult to quantify, and qualitative measures have shown mixed results (RAND, 2005). Requirement attainment objectives and thresholds were another way to facilitate performance trades for cost.

When fully realized, *it is the exclusive use of mature technology in system development programs that is the key enabler of evolutionary acquisition* strategy, facilitating the rapid transformation of applied technology to end-item capability. Thus, it is the third of three principal observations, all of which are paradigm shifts, that we have recently observed: (1) that the DoD would now mandate program strategies for all programs to have multiple product releases of the same item, (2) that requirements would be deferred or allowed to evolve over time, and (3) that high levels of technological maturity would be requisite for commencement of advanced development, with an intended reduction of technical risk (and thus, project schedule) (USD(AT&L), 2003a, May 12, Enclosure—Additional Policy E1.14).

Policy and Implementation Concerns

But there are questions and concerns about these major shifts that several authors have raised. Still a relatively new policy, observations and realizations about the outcomes of evolutionary acquisition and spiral development are only just beginning to emerge, and will continue to surface until at least several major programs go through their entire lifecycle in this way. Sylvester and Ferrera (2003) provided some insight into the challenges and obstacles of evolutionary acquisition implementation—not from program-office level—but from the perspective of strategic policy-makers and subscribers at the Office of the Secretary of Defense (OSD)-level during their struggle to adopt the policy. In short, the authors explained the aforementioned confusion and ambiguity of the policy as it evolved from 1983 toward final promulgation in 2000, and then described the conflict areas caused by shifts in power among the organizational fiefdoms in the OSD and other affected institutions (i.e., Congress and the defense industry). In particular, they exposed the following major stakeholder communities and their respective *areas of concern* about evolutionary acquisition:

- Congress—loss of control over DoD programs via specific and informed authorization and approval; the inability to keep the DoD accountable; unknown implications of requirements and budget flexibility required for evolutionary acquisition.

- Military Departments—need to protect own acquisition programs and share of the DoD budget; retention of funding for follow-on capability increments; increased oversight; downstream logistics of multi-configuration products.

- Defense Industry—disruptions to commercial processes and traditional approaches to business; competition for follow-on increments; lower-rate production runs after shorter R&D efforts.

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[10] Some may also assert that the moratorium against MILSPECS was similar in its thrust to reduce unnecessary work scope, but we believe specifications to be as much prescriptive (i.e., "how") as they are descriptive.

- Comptroller—controlling programs and holding them accountable; unknown implications of requirements and budget flexibility required for EA (program and budget "gaming" by services); "full funding" policy[11] versus open-ended requirements and fund streams.

- Requirements/Users—sub-optimum capability; priority of what is needed versus what is currently attainable; loss of follow-on increments.

- Test and Evaluation—loss of discipline and assurance of operational effectiveness & suitability; lack of comprehensive testing before several low-rate production configurations are released.

We have also had tactical (implementation) concerns about excessive decision bureaucracy (number of DAB reviews—see Figure 1), organizational challenges from multiple and concurrent development efforts, outdated technology at release, funds forecasting, transaction costs, and maintenance of subsequent increment priority. It is these phenomena that we have modeled with computational organizational design tools, which will be discussed later.
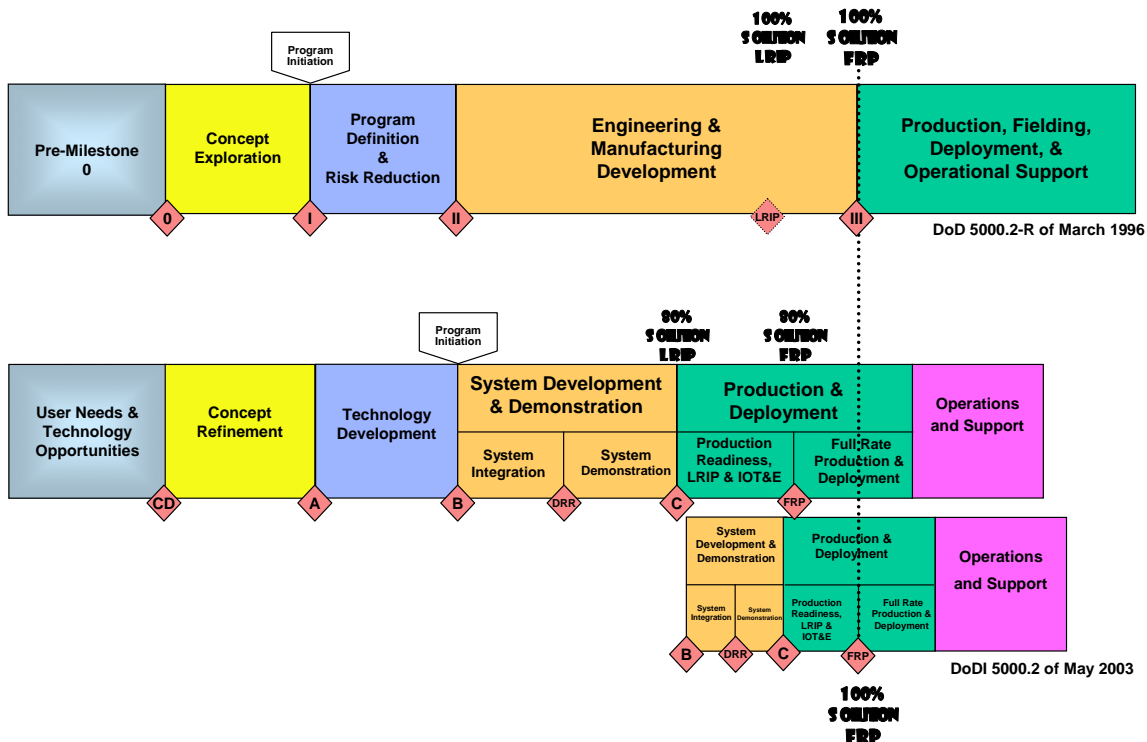
1996 and 2003 DoD 5000 Models

Figure 1. Comparison of 1996 and 2003 Acquisition Framework Models

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[11] The authors explain the dual meanings of this term later in this discussion.

The Costs and Benefits of Variety—and the Need for Control

Evolutionary acquisition methodologies, in addition to potentially adding more concurrency during development, increase variety in production. Both concurrency and variety are elements of complexity and program risk. Variety adds complexity in production and is costly for hardware owners and manufacturers alike. Traditional views about late design changes are negative, except for producibility enhancements and savings or correction of design flaws. But market consumers often need items in rapid cycle-times and appreciate product differentiation. In support of EA policy, the GAO has used product examples such as commercial vehicles. For the most part, we regard these commercial products as relatively "low-tech" on a comparative scale of DoD system complexity and capability. Moreover, we feel the GAO may ignore some very important aspects of ownership, since the DoD is unique as an outsourcer of capitol projects for internal use, and has unique requirements against competitive threats in combat environments.

Control measures are used to manage risk. One way of coping with the complexities of variety in ownership is via organizational and individual accountability. A recent example of successful control of rapid change lies in the Acoustic Rapid COTS Insertion/Advanced Processing Build (A-RCI/PB) program. In this vital program for sustainment of submarine acoustic sensing superiority, a series of hardware and software upgrades were planned and executed in rapid succession. Each emerged with advancement in capability, keeping pace with technology and competitive threats, facilitated by *rigorous control of interfaces, standards and protocols* (Boudreau, 2006).

Many other useful theorems on systems complexity, change and control exist that may be helpful for practitioners to consider, but are beyond the general scope of our research.

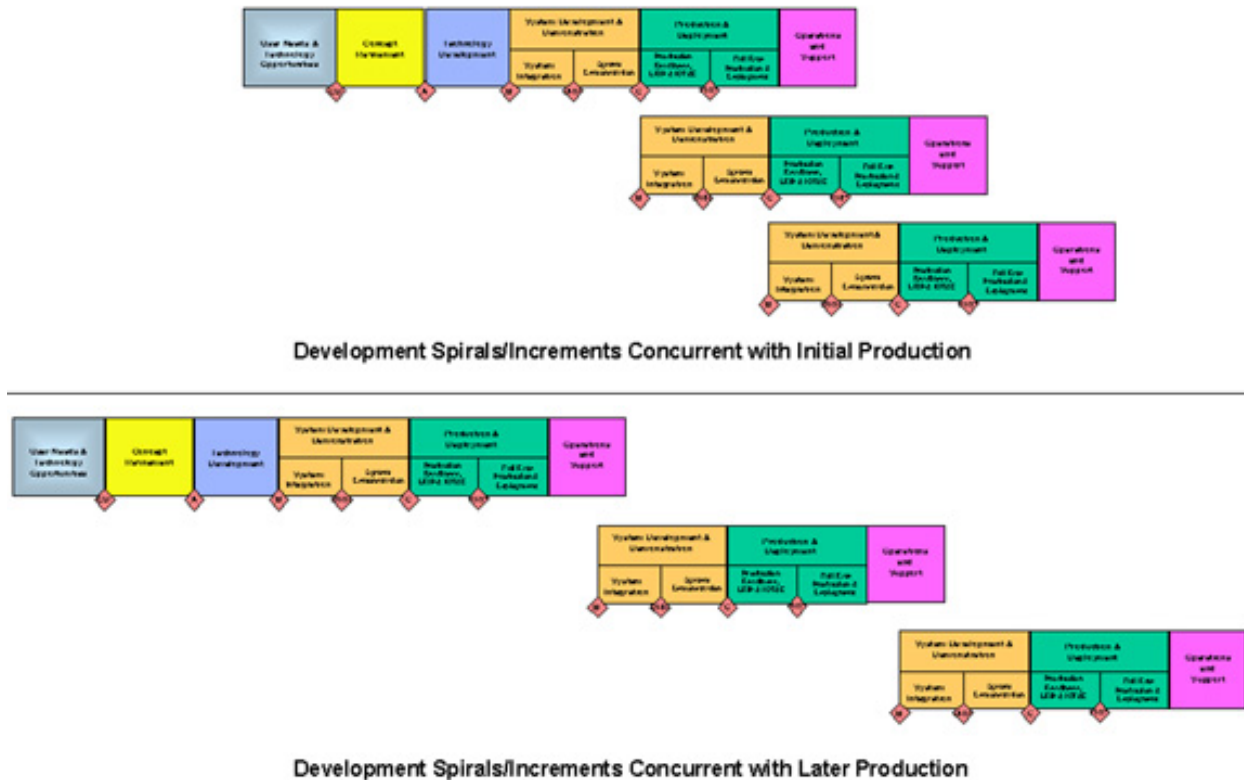### Do Product Attributes Affect Spiral Applicability and Outcomes?

Spiral development as a universal, "one-size-fits-all" strategy may not always be appropriate. Perhaps the foremost reservation is the appropriateness of the spiral development process for all project sizes and product commodities in toto, and the application of the spiral process to hardware products versus Boehm's original and most relevant application of this development approach toward software.[12] We speculate whether certain product characteristics might determine spiral development method applicability, and, thus, may offer important considerations for project planners.

- Mutability simplifies change, and spiral development was conceived for the most malleable of products: "soft" ware, which is virtually costless in production. Multiple product increments do not often appear in large, *static, singular* projects such as bridges, highways, skyscrapers, or in other project areas that have *typically long lead times or product cycles*, such as feature-length films, pharmaceuticals, etc. These are what we call *nearly immutable* products and are much different than smaller projects (like small application software development) with much shorter development periods.

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[12] And the authors will be quick to acknowledge that software is indeed a huge and growing part of hardware systems large and small. Still, the spiral development framework in current literature applies overwhelmingly to the realm of software, not hardware.

- Cycle-time and Phase Concurrency. Akin to relatively mutable or immutable products, we have observed the successive product upgrades visible in long-running aircraft programs (UH-60 Blackhawk and C-130 Hercules as examples) in which there are periods of production configuration stability, followed by improvement efforts, followed by another stable use period. Cycle-time for the development of each increment, and the relatively *successive* or *concurrent* phasing of the follow-on increments, will have a definite impact on program structure, budgeting, project complexity, and organizational issues, etc. For reasons that we will bring forth in our section on the computational modeling of spiral development, we have concerns about the conceptualization of spiral development programs with continuous and highly concurrent phasing of development increments. We suggest that, though concurrency is a necessary ingredient for efficient project management, it has also long been correlated with risk (because of activity interdependency), and might vary significantly with the types of activities underway (See Figure 2)—the inference being that periods of stable production configuration between development increments reduce complexity in program structure and attendant risks. Similarly, shorter cycle-times have less opportunity for knock-on effects or secondary consequences. Particularly in matrix organization structures, as often the case with projects, there can be a tendency to staff multiple projects with a single specialist. The more projects a specialist supports, the less they are *proportionately* available to the projects due to "queuing inefficiencies."Availability decreases because of the need for transition between projects (physical, mental, learning curve, etc.).

  - The end result has sometimes been shown to be large delays in project completion (Smith & Reinhartsen, 1998).

  - Similarly, Ibrahim (2005) has shown that discontinuous enterprise membership is a contributing factor toward knowledge loss in organizations involved in large, complex product development processes. Examining knowledge flows across product lifecycles, members often are not engaged in all phases. Whether from rotation of duties or multi-tasking, a discontinuous member's inaccurate knowledge could cause a functional error at the individual level which is not obvious at the enterprise's overall project level. These findings support observations of knowledge loss continuing despite investments in information technology and knowledge management.

Development Spirals/Increments Concurrent with Initial Production

Development Spirals/Increments Concurrent with Later Production

Figure 2. Concurrency Relative to Types of Activity

- User Risk (Safety and Time Criticality). Time criticality and life-saving dependency, as opposed to user hazard levels (safety & man-rating), might seem to also have influence over design approaches. We have discussed above the area of technological risk and the DoD's use of incremental or spiral approaches to resolve it (along with a compulsory policy for the advanced development of only relatively mature technology). But DoD products have expanded risk considerations beyond Boehm's models of commercial software. Extending the idea of project risk-as-a-driver down to the level of the end-user, it might seem logical to assume that time criticality of the need or mission, where risk of not achieving project success actually endangers customer lives, might be a significant factor in the appropriate application of the spiral process for reduced initial product cycle-time. Perhaps defensive systems are a good example. The immediate needs for a Rocket-Propelled Grenade (RPG) defeater or an Improvised Explosive Device (IED) neutralizer for currently deployed forces in Iraq and Afghanistan, for example, clearly dictate that lives will be lost if a near-term capability is not achieved. We also cite as an example the National Missile Defense (NMD) initiative, in which, in view of near-term threats, early deployment of even rudimentary capability has been deemed preferable to waiting for full capability. Such urgency likely precludes full and certain requirements specificity.

  - Non-man-rated Systems: In an almost opposite vein, non-man-rated systems, such as Unmanned Aerial Vehicles or cave-exploring robots—capabilities in which operator lives are not at risk if the product fails—may also lend themselves readily to rapid innovation and risk-less experimentation cycles. However, user hazard levels for man-rated systems may be a different matter.

- Man-rated Systems: Configuration variety adds technical complexity with unpredictable interactions. In such projects as pharmaceuticals, aviation, vehicular transportation, etc., producers mitigate safety risks with thorough analyses, documentation reviews, testing and other control and verification processes. By their very nature—with lethal hazards for the end-user, and typically lengthy approval requirements—these may not be good candidates for a spiral approach. We believe this is why space experts say they'll not use spiral development with NASA's new Crew Exploration Vehicle (Roy, 2006).

- Production Quantity. As to product size or production quantity, we find no evidence that either precludes use of spiral—as with space vehicles and large ships—though support considerations do arise with variety that could greatly affect total costs of ownership.

- Logistical Support planned during Service/Shelf Life. Our observations warn that multiple configurations of hardware products do come at a cost for ownership. Veterans of new system deployments across the force/fleet, or throughout any large using organization, know the difficulties of rolling out a configuration change. Benefits of standardization have long been offered via production economies of scale, commonality of parts across platforms, and interoperability. If the ultimate goal is to have standardization across the DoD's force, owning multiple configurations of a system (variety) equates to added complexity in training and supply support of the item. Neither can the logistical maintenance strategy be ignored: whether the end-item is maintenance-intensive (such as tactical vehicles) or maintenance-free—such as with many electronics items and munitions, and situations in which physical changes are completely transparent to the user. For multiple product configurations, the answer could have a huge effect on the total costs of ownership, as shown by RAND on the proliferation of UAVs (Shaver & Amouzegar, 2005).

- Range of Requirement Attainment. Certain requirements are binary rather than continuous. Examples are soft launch, network security, physical fit, leak-proof, shock/vibration/drop proof, survivability, horizontal-to-vertical flight transition, etc. If one of these more binary-type requirements happens to be a key performance parameter, its attainment will be on the project's critical path and highly dependent upon technical maturity. As such, it may practically dictate the length of the entire advanced development effort and make division into capability increments less beneficial as a development strategy.

- Amount of Change—and the Lure of Modularity. These authors subscribe to the current theorists' view that system complexity is comprised of numbers (of components), connections (interdependencies) and distinctions (variety). Distinction corresponds to variety, to heterogeneity, and to the fact that different parts of complex systems behave differently (Heylighen, 1997). Variety is a component of Nobel Prize winner Herbert Simon's explanation of complexity—many different parts with many interactions. Simon argues, from his observation of complexity in things both natural and artificial, that complex systems evolve from simple systems. And they do so more rapidly when there are stable, intermediate forms or sub-systems (like modules or "units of action") (Simon, 1981). While the concept of modularity suggests approximately independent subsystems may be modified or adapted as such, it has been shown that, in the aggregate, there is yet quantifiable modular interdependency that affects evolvability (Watson & Pollack, 2005). In other words, how changes in the state of one module affect the state of another is relative and measurable. Thus, we suggest it is not only the focus upon structural modularity as such, and, standard interfaces, that enable systems evolution. Rather, it is the relative interdependency of the modules. In short, PMs need to be

mindful of the degree of change in subsequent spirals. One subsystem is likely to affect another in the short- or long-run. And that can make product evolution problematic. As Norman Augustine once said, "No change is a small change"; independent subsystems, even redundant ones, aren't always independent (Augustine, 1997, June).

Development Case Studies

One of the most recent monographs we have found on emerging results of evolutionary acquisition is by RAND—on five immature, non-man-rated space systems. Space systems are somewhat different (in quantities, space environment, front-end investment, and extended technology development periods) than other DoD sytsems. RAND also found that policy confusion persists, and that EA added program complexity and uncertainty, especially with regard to budgeting. Extending their findings to non-space DoD programs, RAND highlighted the EA challenges of programmatic flux. They feel, and we agree, that EA presents the opportunity for typical PM challenges to be even more formidable.

Two missile programs were used as case studies for analysis and to illustrate planned and unplanned change. ATACMS used incremental and spiral strategies for product development. The program skipped its technology development phase by employing mature technologies for a leap-ahead capability in range. It arrived on budget and schedule, with several successive variants, pre-planned and unplanned. One instance of production change caused missile failure and costly refit of already produced missiles—underscoring the need for more thorough design specification and configuration management accountability.

Javelin used the single-step-to-full-capability approach to product development. The program embarked upon advanced development with immature technologies in several critical areas, causing significant cost and schedule overruns. It also has had subsequent design changes and product variety, more so as running production changes than as product variants.

Synthesis of these cases conveys that as an approach oriented primarily for reduction of product cycle-time, incremental or spiral development can successfully be used when developing mature technologies first. But a system's physical properties like mutability, along with other factors such as time criticality (user risk) and modular interdependency, will drive spiral development applicability. And key capabilities may in fact depend upon the least mature technologies or even binary requirements. An "open," or at least elegant, architecture is key to forming a basis for independent modular variety; and thorough design specification and configuration management accountability is essential for managing the complexity of multiple product releases. All amorphous spirals eventually become defined increments. Other well-known programs have used a spiral approach over their long product life spans, but often have successive phasing of their development increments.

Computational Modeling of Spiral Development

A computational experimentation approach to investigating evolutionary acquisition projects is explored below. This approach integrates theory and practice in a computational tool that allows controlled experimentation through simulation. The current work reflects project theory (e.g., the theory of constraints and work flows), product development theory (e.g., rework impacts and work dependencies), and management (e.g., resource management and information theory). Practice is reflected in the model through the use of case studies to build and validate the model structures (as described in the literature cited) and the calibration and testing using the acquisition projects described above. A computational experimentation

approach provides many advantages over pure and benefits from several of the strengths of both laboratory and field research. Nissen and Buettner (2004) describe and discuss the computational experimentation approach, and Dillard and Nissen (2007) describe its application to investigating acquisition projects.

The system dynamics methodology was applied. System dynamics uses a computational experimentation approach to understanding and improving dynamically complex systems. The system dynamics perspective focuses on the roles of accumulations and flows, feedback, and nonlinear relationships in managerial control. The methodology's ability to model many diverse system components (e.g., work, people, money), processes (e.g., design, technology development, quality assurance), and managerial decision-making and actions (e.g., forecasting, resource allocation) make it useful for investigating acquisition projects. Forrester (1961) develops the methodology's philosophy, and Sterman (2000) specifies the modeling process with examples and describes numerous applications.

Modeling Incremental Development with Multiple Development Blocks

Figure 3 depicts an acquisition project with multiple increments or blocks. Subsequent blocks have the same basic information flow, but can also be delayed by the completion of phases in previous blocks or constrained by the progress in their own blocks. Importantly, in addition to the flow of information downstream through phases (black arrows in Figure 3), multiple iteration acquisition also provides opportunities for information to flow upstream, such as from User Product Testing in an earlier iteration to Develop Requirements or Advanced Development in a subsequent iteration (red vertical arrows in Figure 3).
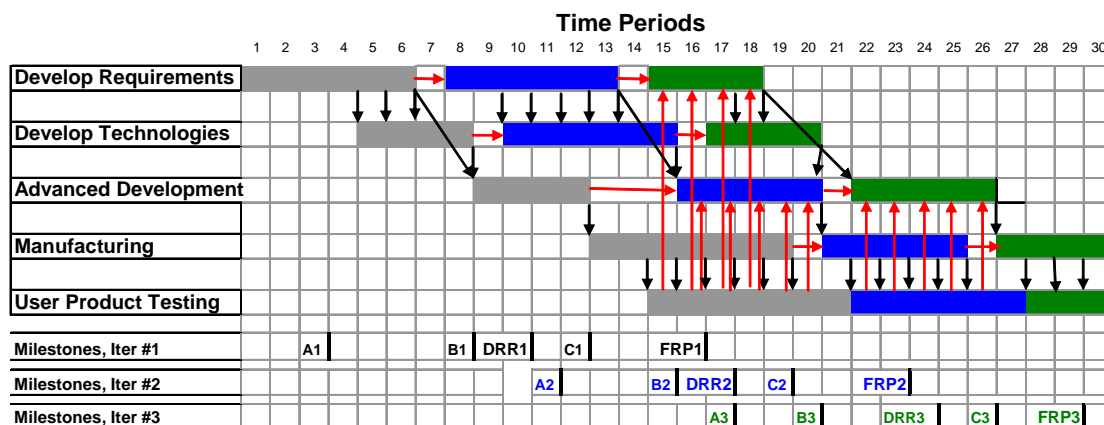
Figure 3. Information Flows in an Incremental Acquisition Project

In the model, the structure of each block is the same, although parameter values are varied to reflect different acquisition projects and strategies. For example, all phases include start-up work that is not directly applied to generating development products (requirements, technologies, component designs, or products). Each phase also includes the requisite review work that also does not directly generate product. This is consistent with GAO recommendations to manage each development block like an individual project. One impact of this loading of each phase with start-up and review work that we suspect has only been recognized informally is a significant increase in the total amount of work required to provide a given set of requirements to warfighters when multiple development blocks are used. As was

shown with our modeling results, this work has a significant impact on project performance that may impact the types of projects in which spiral development can be effective.

Computational modeling of incremental/spiral versus a single-step methodology yields results that illustrate our implementation concerns. Spiral development can provide the initial increment delivery with some (but not all) requirements satisfied earlier than in single-block development. However, spiral development takes more time and costs more to satisfy all requirements than single-block development. Spiral development has a high risk of not satisfying all requirements by the time single-block development can satisfy all requirements (See Table 1).

		Units of Measure	**Project Scenario**		
			Javelin	Base Case - traditional	Base Case - spiral
Performance Measure	**Duration to first requirement satisfied**	weeks	471	***470***	<u>**397**</u>
	Duration to max. requirements satisfied	weeks	520	<u>**518**</u>	***762***
	Total development cost	$1,000,000	722	<u>**719**</u>	***1,555***
	Requirements satisfied by deadline	%	<u>**100**</u>	91	***18***
	Final requirements satisfied	%	<u>**100**</u>	***91***	***91***

Table 1. Performance Comparison of Three Simulated Acquisition Projects

The causal paths that drive and constrain project performance in spiral development pass through multiple types of resources, development processes, and move across both development phases and development blocks. They also vary widely for different performance measures. This makes the drivers of and constraints on spiral acquisition project performance more difficult to identify than those in single-block development projects. Our modeling results indicate that spiral development is a significantly different approach to acquisition than single-block development, and requires different planning, resourcing, and management.

The concurrent use of multiple development blocks in spiral development significantly increases the number of development phases and activities that must be managed and coordinated at any given time compared to single-block development. This increases the project management needs for successful acquisition in spiral development projects compared to single-block projects.

As in single-block development, progress in spiral development requires the identification and understanding of progress bottlenecks. The concurrence and resulting complexity of development in spiral projects causes the types and locations of bottlenecks to vary widely and be more difficult to identify and address than in single-block development.

Causal paths of the drivers and constraints on project performance and progress bottlenecks move from one feature of a project to another as projects evolve. The increased dynamics of development in spiral development projects, as compared to single-block development, make identifying and addressing causal paths and progress bottlenecks more difficult. Progress bottlenecks can cause counterintuitive behavior, such as reductions in project cost, by adding resources at a bottleneck. Understanding and exploiting the opportunities provided by these behaviors requires a deep understanding of the project structures and dynamic interactions that drive and constrain progress.

Discussion—Recent Views on Balancing Risk and Control

Boehm's latest book on software development advocates balancing disciplined and agile methods to capitalize on the benefits of both. Discipline is needed as a control mechanism to avoid risk, but agility is needed to respond quickly to customer needs. Saying, "One size fits all is a myth"; he advocates a balanced approach based upon risk. He also advocates the more disciplined, risk-averse approaches for projects that are mission/safety critical, larger in size, and have more stable requirements (Boehm, 2004).

It could be summarized that spiral development was at its inception and is at its extension all about risk. Paradoxically, it is an agile method envisioned to reduce risk and, yet, can potentially add its own. On the one hand, a spiral or incremental approach allays risk by reducing scope to render only the highest priority capabilities with the exclusive use of mature technology, and obtains early and continuous feedback from the environment for follow-on developments. On the other hand, it introduces concurrency during advanced development and adds variety in production, with all their attendant management challenges.

Observations and Assessments

Although today's policy of evolutionary acquisition is prescribed as a development methodology, it is actually focused more upon what—not how—we develop. As such, it is about doable scope, reducing risk via exclusive use of mature technology. The Cost As an Independent Variable and other requirement-limiting initiatives were earlier attempts to accomplish this, by encouraging product performance trades to keep cost estimates fixed. As with CAIV, this likely means trading performance requirements for earliest-deploying increments.

Spiral development also seeks to spread out the technical risk over more development and process time via incrementing. We have shown with simulation that this can potentially improve risk management performance initially, but with higher overall costs and longer subsequent development durations, if deliberately deferring known, estimable work. As such, our computational modeling indicates that incremental development costs more and requires more time to provide the same requirements than single-step development. With regard to project risk, the increased complexity in a project using an incremental or spiral approach makes the isolation and effective management of progress bottlenecks more difficult than in single-step development.

The policy change is that spiral development now includes undefinitized increments and prescribes incremental development instead of single step development. All amorphous spirals will eventually become defined increments—mini-programs. In years past, they have often been implemented as sequential, separate, and successive product upgrades (such as the CH-47,

UH-60, C-130, B-52 program examples). But current policy expresses these as more concurrent, frequent and continuous. Such concurrency adds complexity to development models, with attendant risks of over allocation of work, noise, error, duplication, and other inefficiencies from work deferral and divided effort in project management organizations. Additional oversight, reviews, contracting, testing, etc., will also likely affect transaction costs. If all requirements are known and an incremental approach is used, then there is a deliberate deferral of work to later increments, and there will be a resultant increase in total development costs and durations for these same reasons.

Recommendations for Practice

1. Project managers need to be aware of the inherent risks of spiral development and take necessary precautions to balance those risks. Many tools and control measures are currently developed and available to assist project managers in balancing the risks of spiral development, such as technology readiness levels, configuration management, technology performance management, real options, project phasing, risk management, earned value management and organizational design.

2. Incremental and spiral development projects provide additional _opportunities_ for managing development risk in the project design. These include project-planning decisions about the number of development blocks, the requirements and associated technologies and design components to be included in specific blocks. This planning provides opportunities to anticipate where critical progress bottlenecks may occur and design how to best monitor potential bottlenecks and respond to them.

3. Product attributes may help determine the suitability of spiral development as the best methodology. PMs may wish to consider such characteristics as: mutability, time criticality, man-rating, modular interdependency, key parameters of capability versus range of requirement attainment (i.e., binary vs continuous), and the relative amount of concurrency among increments.

4. Progress bottlenecks in iterative and spiral development often oscillate between process constraints (e.g., availability of work due to upstream progress) and resource constraints (developer or project management quantities or productivities). Successfully addressing a constraining progress bottleneck often shifts the limit on progress to a different location in the project. Therefore, a structured and interdisciplinary practice of identifying and addressing bottlenecks can improve performance.

5. Configuration management accountability must be assigned or kept to maintain supportability and failure-mode identification and causality and prevent the variety generated by spiral development from reducing total product performance.

Conclusions

We've suggested that a one-size-fits-all methodology for DoD system development may not be appropriate, and have offered for consideration several product attributes that might help determine the efficacy of the spiral approach. We further suggest that spiral development may serve better than single-step development for initial capability when products are mutable, time-critical, non-maintenance intensive, and have continuous (vs. binary) or uncertain requirements, short cycle-times (less knock-on effects), sequentially phased development, and modular

independence. In contrast, spiral development may not be appropriate when there are safety or man-rating concerns and have attributes opposite to those above. In particular, PMs should understand the nature of their product requirements with regard to their range of attainment and relative to key parameters of capability, and vis-à-vis the readiness level of their enabling technologies. Some key features may indeed be binary, and others may have significant ramifications of partial attainment—such as propagated change across the entire product componentry (as in weight reduction), versus a more independent, modular modification.

Open design standards will not always be incorporable. And product variety will emerge, with and without backward compatibility, interoperability, etc. Variety is both an asset (for end-users) and a liability (for manufacturers, owners and supporters). As such, to compensate for product variety, "owners" must "own" the design and emphasize configuration management, keeping or assigning responsibility for that function, and maintaining *accountability* for it.

Both *product specification*s as well as *risk realization* in spiral development move from being amorphous to defined. Spiral development has inherent challenges, both strategic and tactical, of which PMs must be aware. We've highlighted and illustrated them here, as well as showing (in our case studies) that spiral development can indeed work—especially for technically mature and mutable products with open or elegant architecture. Program Managers must be aware of these inherent risks, and take necessary precautions to balance them with increased use of tools, such as technology readiness levels, configuration management, technical performance measurement, contract incentives, options and phasing, organizational design, etc.

Stability is the quest in all things programmatic—for funding, requirements, design, configuration, etc. But in an unstable world, and with the future being necessarily uncertain, the tension between control and change is probably unending. PMs do have some tools for coping, and being forewarned is being forearmed. PMs are used to concurrency and change, as they are largely what make project management what it is—a balancing act. Mechanisms for control of risk include project management tools such as configuration management, technical performance measurement, earned value management, risk management, etc. Organizational and cultural factors such as leadership, trust and accountability play a significant role as well. Successful use of these tools to balance control and risk in projects with a high rate of change and concurrency is an area for our further study.

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Panel 17 - Topics in Cost Estimating & Analysis

Thursday, May 17, 2007	Panel 17 - Topics in Cost Estimating & Analysis

1:45 p.m. – 5:00 p.m.	**Chair:**
	
	Russell A. Vogel, Executive Secretary of the OSD Cost Analysis Improvement Group
	
	Discussant:
	
	Robert Flowe, Senior Cost Analyst, OSD Cost Analysis Improvement Group
	
	Papers:
	
	Applying Insights from Transactions Cost Economics (TCE) to Improve DoD Cost Estimation
	
	    Raymond (Chip) Franck, Diana Angelis, Francois Melese and **John Dillard**, Naval Postgraduate School
	
	Managing Uncertainty and Risk in Public-sector Investments
	
	    Richard Suter, RS Consulting
	
	Dynamic Cost-contingency Management: A Method for Reducing Project Costs while Increasing the Probability of Success
	
	    Edouard Kujawski, Naval Postgraduate School
	
	An Enterprise Model of Rising Ship Costs: Loss of Learning Due to Time between Ships and Labor Force Instability
	
	    Richard L. Coleman, Sector Director, Northrop Grumman Cost/Price Analysis Center of Excellence

Chair: Russell A. Vogel, Executive Secretary of the OSD Cost Analysis Improvement Group

Discussant: Robert Flowe, Senior Cost Analyst, OSD Cost Analysis Improvement Group, has particular interest in the acquisition management implications of Joint Capabilities and is the project leader for the CAIG-sponsored research activity on System of Systems cost drivers. Flowe retired from the U.S. Air Force in 2003. While on active duty, he served on the faculty of Defense Acquisition University, where he managed and taught the Intermediate Software Acquisition Management Course. Flowe has a BS in Aerospace Engineering from Virginia Tech, and an MS in Software Systems Management from the Air Force Institute of Technology.

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Applying Insights from Transaction Cost Economics (TCE) to Improve DoD Cost Estimation

Presenter: Raymond (Chip) Franck, PhD, Senior Lecturer, Graduate School of Business & Public Policy, Naval Postgraduate School, retired from the Air Force in 2000 in the grade of Brigadier General after thirty-three years commissioned service. He served in a number of operational tours as a bomber pilot; staff positions which included the Office of Secretary of Defense and Headquarters, Strategic Air Command; and was Professor and Head, Department of Economics and Geography at the US Air Force Academy. His institutional responsibilities at NPS have included the interim chairmanship of the newly-formed Systems Engineering Department from July 2002 to September 2004, teaching a variety of economics courses, and serving on a number of committees to revise curricula for both the Management and Systems Engineering disciplines. His research agenda has focused on defense acquisition practices and military innovation.

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Author: John Dillard joined the NPS faculty in the fall of 2000 with extensive experience in the field of systems acquisition management. His research focuses on defense acquisition policy changes and their implications. Dillard began his career in program and contract management after attaining a MS in Systems Management from the University of Southern California in 1985. He has been involved with myriad technologies and system concepts that have evolved into fielded products, such as the M-4 Carbine, 120mm Mortar, and M-24 Sniper Weapon. He was the Assistant Project Manager for Development of both the Army Tactical Missile System and, later, the JAVELIN Antitank Weapon System at Redstone Arsenal, Alabama. All of these systems incorporate state-of-the-art technologies, are in sustained production and fielding, and are now battle-proven. He was the Product Manager for the Joint Advanced Special Operations Radio System, and in 1998 was appointed to head Defense Department contract administration in the New York metropolitan area. Dillard has consulted for the governments of Mexico and the Czech Republic on achieving excellence in the public sector. As an adjunct professor for the University of California at Santa Cruz, he teaches courses in project management and leadership to Silicon Valley public- and private-industry professionals.

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I. Introduction

There is mounting evidence of a systematic bias in initial cost estimates of new weapon systems. A comprehensive 2006 RAND report on major weapons programs concludes: "[The] analysis indicates a systematic bias toward underestimating the costs […] of a weapon system." (Arena 2006, p.1). This bias could threaten our national security. Unrealistically low cost estimates result in cost overruns. Fixing cost overruns can impact military readiness.

Two factors are usually blamed for unrealistically low cost forecasts: bad incentives (psychological and political-economic explanations) and bad estimates (methodological explanations). The focus of this study is on cost methodology. Our goal is to contribute some new ideas to the current literature on cost estimating. This paper applies Transaction Cost Economics (TCE) (e.g., Williamson, 1985; Dillard, Franck & Melese, 2006) to help characterize, explain, and ultimately reduce the cost growth that plagues many of today's major investments in military capabilities.

In business, two costs are typically factored into the "make-or-buy" decision: production costs and the costs of managing transactions—"transaction costs" (Coase 1937). Conventional estimation techniques tend to focus on production costs (input costs, learning curves, economies of scale and scope, etc.). TCE emphasizes another set of costs—primarily the costs of coordination and motivation (e.g., search and information costs, decision and contracting costs, monitoring and enforcement costs). The primary insight drawn from TCE is that correctly estimating the economic production costs of an acquisition is necessary, but not sufficient. The choice of contract, organization, and incentives, along with key characteristics of markets and

transactions (uncertainty, complexity, asset specificity, frequency, and contestability), must be included to obtain reliable cost estimates.

II. Background

A recent Government Accountability Office (GAO) study cites multiple examples of weapon systems cost increases. The GAO reports significant unit procurement cost increases for several familiar programs. The Joint Strike Fighter saw unit procurement costs increase over 25%, the Army's Future Combat Systems over 50%, while the Air Force's F-22A Raptor experienced almost 200% procurement cost overruns (GAO April 2006, p.5). According to another GAO report, "[p]rograms consistently move forward with unrealistic cost […] estimates" (GAO Mar 2006, p.1).

Traditional cost estimating relies on a Work Breakdown Structure (WBS). Similar to an economist's production function, a WBS captures the mix of inputs and activities required to produce a specific weapon system. Cost estimates developed for each component of the WBS are rolled up into an overall estimate for the project. Also, simulation methods can be used to capture uncertainty and provide a distribution of possible weapon system costs. Confidence intervals applied to this distribution allow cost estimators to report probabilities associated with specific ranges of costs for a particular weapon system. However, the confidence in these cost estimates depends *inter alia* on the completeness of the model. TCE offers complementary considerations that can impact the costs of major weapon systems, many of which are known but not explicitly factored into traditional cost estimates.

In its recent review of the literature, a RAND study reports, "our analysis […] shows that, by and large, the DoD and military departments have underestimated the cost of buying new weapon systems" (Arena, 2006). Virtually all the studies that RAND examined found a systematic downward bias in cost estimates. The average cost growth over initial forecasts of weapon systems in the development phase ranged from 16 to 26%. Estimates of procurement cost growth averaged between 16% and 65%, while total weapon program cost overruns averaged between 20 to 54%.

Cost estimates serve two main functions. First, they serve as an integral part of the decision process (cost-benefit or "analysis of alternatives") used to evaluate military investments. Second, they provide the foundation for future defense budgets.

In the first case, underestimating costs can result in overestimates of the affordable quantity of those weapons. It can, therefore, result in too many new weapon program starts and excessive investments in those systems. In the second and related case, unrealistically low cost estimates result in overly optimistic budgets. Budgets planned on the basis of optimistic cost estimates create the illusion of more resources available than actually exist. Since acquisition budgets are, in essence, a contract for major weapon systems between the DoD and Congress, unrealistic cost estimates can lead to a breach of trust and can poison relations between the branches of government.

One method used to cope with cost overruns is to stretch out programs and cut quantities that reach the force. But this sacrifices both current and future operational capability. Moreover, spreading fixed costs over fewer units increases unit production costs. The end result can be to get less (quantity) for more (money). Another method to pay for cost overruns is finding savings in training, operations, and maintenance budgets. But this also risks sacrificing current and future operational capability. Reprogramming money from other programs to

accommodate cost increases is another approach. But this is a limited remedy (constrained to no more than $10M in RDT&E and $20M in Procurement within a program element) and can have a negative and cascading effect on other programs' costs, schedules, and performance. The net effect of cost overruns is clear. Short of a bailout from Congress, systematically underestimating costs reduces the overall readiness and availability of military forces and equipment.

III. Alternative Explanations of Unrealistic Cost Estimates

The two factors commonly used to explain "unrealistic cost estimates" are bad incentives [due to optimism bias (psychological explanation), or perverse bureaucratic incentives and strategic misrepresentation of budgets (political-economic explanation)], and bad estimates [imperfect forecasting techniques such as an omitted variable bias (methodological explanation)]. It is helpful to examine these factors in the context of the Planning, Programming, Budgeting and Execution (PPBE) process used by the DoD to build the nation's defense budget.

In theory, "Programming" involves a constrained optimization in which investment and operating decisions are made to maximize national security subject to fiscal constraints. The Secretary of Defense (including OSD Program Analysis and Evaluation (PA&E) and the DoD Comptroller) and the Chairman of the Joint Chiefs of Staff have good reasons to prefer accurate cost estimates given their global optimization perspective.

In contrast, given their sub-optimizing perspectives, Combatant Commanders and the Military Services (for instance) may be more subject to a bias toward optimism and to perverse bureaucratic incentives. Since their primary focus is on performance and military capability, they have reason to be less critical (and realistic) in their cost estimates.

According to McNicol (2005, p. S-4), "statistical analysis is consistent with the well-established presumption that the military services tend to prefer [...] optimistic procurement cost estimates." Program Element Monitors (PEMs), for example, act as advocates for the funding of their programs and are responsible for defending those programs throughout the PPBE cycle. Since all programs compete for the DoD's limited resources in a particular funding categories, PEMs are well aware that resource allocation is a competitive, constant-sum game. Given their job descriptions, PEMs are drawn to lower cost estimates that fit their advocacy agendas, rather than to higher cost estimates which make defending their programs more difficult. Moreover, since they do not always posses a higher-level perspective, they may not fully appreciate how underestimating costs can impact other programs.

Also, defense companies have good reasons to strategically underestimate costs since this makes their programs more attractive to the DoD and the Congress. Here, the logic can be interpreted by leveraging one of the hallmarks of TCE, the "fundamental transformation" (Williamson, 1996). The standard example is when *ex ante* competitive bidding leads to an *ex post* bilateral monopoly situation. The risk is that the winning supplier can lock in the Government by making investments in productive assets that are specific to the relationship (and that have little value outside the relationship). Once the DoD "buys in," defense firms can lock in their customer by investing in specific assets (e.g., production facilities) that act as barriers to entry. While initially advantageous, such investments in specific assets can make it prohibitively costly for other companies to compete in subsequent re-bidding of the contract.

Given the complexity and uncertainty of many major, technologically advanced weapon systems, contracts are necessarily incomplete; i.e., they cannot cover all possible contingencies. As a consequence, the incumbent company can be confident it will recoup overruns from multiple change-orders (generally for added scope) anticipated over the life of the contract. In fact, firms have an incentive to anticipate, but strategically omit, some of these elements in the original contract negotiation. Moreover, by strategically hiring workers in key Congressional districts, the company can pressure Congress to retain the contract and approve compensation for cost overruns to preserve jobs. This combination of strategic behaviors could explain some of the systematic bias in initial cost estimates.

Therefore, cost-estimating techniques must properly anticipate transaction costs such as measurement, monitoring, management and re-negotiation costs that can quickly overwhelm initial production cost estimates, and which vary according to the nature of the transaction. If TCE considerations are not properly anticipated, the result will be that cost-estimators will continue their downward bias, and programs will continue to suffer cost overruns. One possible means to improve DoD cost estimation is to add transaction cost considerations to the current production cost focus in cost-estimating methods.

In an early attempt to address the factors that lead to biased cost estimates, Secretary of Defense Melvin Laird directed that independent parametric cost estimating be made a part of the DoD acquisition process. The Office of the Secretary of Defense (OSD) launched an independent Cost Analysis Improvement Group (CAIG) that began operations in the Spring of 1972. Eventually, the CAIG was assigned the statutory responsibility of providing independent lifecycle cost estimates for all major weapon acquisition programs. According to McNicol (2005), "the introduction of independent parametric costing […] had a major, continuing effect on reducing procurement cost growth" (p.44).

Whereas independent cost estimation is an important step that clearly attenuates the impact of psychological and political-economic factors, the challenge of developing a more comprehensive cost estimating/forecasting methodology remains. Hence, the primary focus of this study is to leverage insights from TCE to improve the DoD's cost estimating/forecasting methodology—while recognizing those other causes of bias in cost estimates.

The next section (IV) reviews traditional cost estimating. The following section (V) reviews some key contributions of Transaction Cost Economics. Section VI introduces two sets of hypotheses relating to DoD cost estimating and describes how insights from TCE might be leveraged to improve DoD cost estimation. The following section (VII) of the paper offers two case studies interpreted in the context of TCE. Section VIII reports our search for evidence of transaction costs found within program office budgets and its results. The concluding section (IX) offers some policy recommendations to improve future DoD cost estimating/forecasting.

IV. A Brief Review of Cost Estimating in the Department of Defense

In the defense acquisition process, a cost estimate is a prediction or forecast of the cost of a program or weapon system. *DoD Instruction 5000.2* requires that both a program office estimate and a DoD component cost-analysis estimate be prepared in support of acquisition milestone reviews. For major defense acquisition programs, these estimates are subject to review by the OSD Cost Analysis Improvement Group (CAIG). In addition, the CAIG performs an independent lifecycle cost estimate for all ACAT ID programs and for certain ACAT IC programs.[13]

The first step in any cost estimate is to understand the attributes of the program or weapon system whose cost is to be estimated. Traditionally, this requires understanding and describing the weapon system in terms of physical and technical parameters, operational and support concepts, mission requirements, and interfaces with other systems. Understanding the program's schedule and acquisition profile is also important in developing a cost estimate. The goal is to understand the relationship between key weapon system attributes and cost. For programs reviewed by the CAIG, this first step is documented in the Cost Analysis Requirements Description (CARD), according to the guidelines in *DoD 5000.4-M.*

The second step is to develop an explicit framework for the cost estimate. The Work Breakdown Structure (WBS) is a hierarchy of weapon system components (hardware, software, data, facilities, and services) that attempts to capture economic production cost elements of the estimate. A WBS is developed by subdividing a product, process or service into its major work elements and sub-elements. The highest level, the system WBS, can be organized according to the lifecycle phases of a system: Research & Development, Investment, Operating and Support and Disposal.

Under each phase, a hierarchical structure documents the activities and resources required to complete the work associated with that phase. Under the Investment phase, for example, the Program WBS encompasses the entire acquisition program, including production costs derived from the Contract WBS. This defines at an aggregated level what is to be procured and consists of at least three program levels with associated definitions.

The Program WBS is used by the Government program manager and contractor to develop and extend a Contract WBS. It contains uniform terminology, definitions, and placement in the input-oriented family tree structure. The contract WBS provides the structure for information contained in the Contractor Cost Data Reporting System and other cost performance reports and is defined by *Military Handbook 881A*. Operating and Support costs are organized in a Cost Element Structure in accordance with CAIG guidance, similar to the way the WBS is used to organize development or production costs. An example of a program WBS is shown in Figure 1.

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[13] Acquisition Category (ACAT) I is defined by *DODI 5000.2* as a major defense acquisition program (MDAP) that either has a dollar value estimated by the USD(AT&L) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars, or has been designated of special interest by the Milestone Decision Authority (MDA). (DODI 5000.2, enclosure 2)

The level of detail in the WBS evolves as the system is defined and developed throughout its lifecycle.   After the program WBS has been approved, the contractor will then extend the contract WBS to the appropriate lower levels to better define the complete scope of the contract. When integrated with the program WBS, the extended contract provides a complete WBS for the acquisition program. Similar to the economists' production function, the WBS reveals all the key inputs required to generate the ultimate output/product.
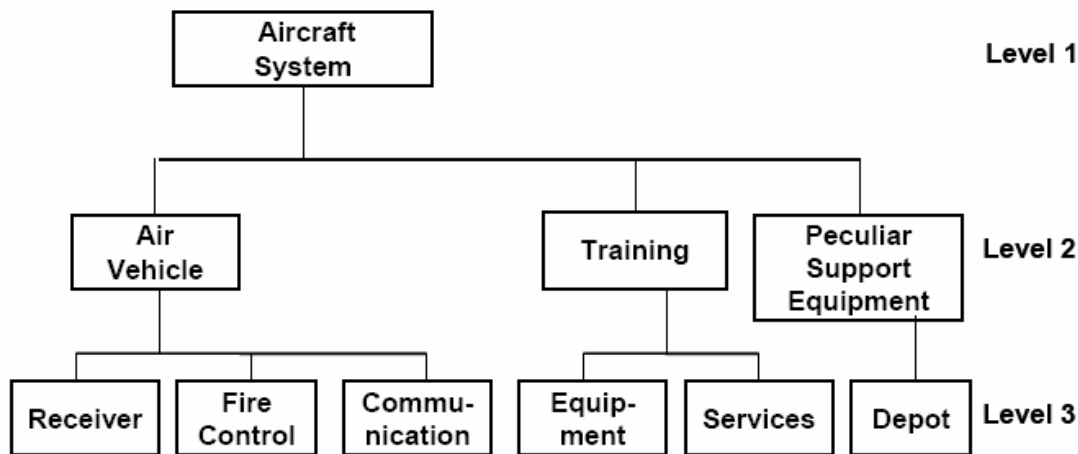

Figure 1. Program WBS
(DoD, 2005)

The next step is to develop a cost estimate. From the WBS perspective, the total cost of the system is obtained by adding up the cost of the individual elements (inputs) in the hierarchy across the levels of the WBS. In order to do this, a cost estimate must be generated for each element of the WBS. The level of detail of the cost estimate depends on the amount of information available about the system. In the early stages of development, there are only rough estimates of the system parameters/attributes; therefore, only the highest levels of the WBS cost can be estimated using "rough order of magnitude" or "top-down" techniques such as analogy and parametric or cost estimating relationships (Blanchard, p. 595). For example, the estimated cost of a new aircraft may be modeled as a function of the weapon system's key inputs/attributes like empty weight, speed, useful load, wing area, power, and landing speed. This model estimates the total cost of the aircraft based on a set of parameters independent of the WBS structure.

As more information about the system becomes available, more detailed estimates can be developed for lower levels of the WBS using a variety of techniques. A cost estimate is now developed for each element at a given level of the WBS. For example, the cost of the aircraft wing may be estimated using historical data for weight, area, and materials. While this estimate is still based on the parametric technique, the level of detail (a wing) corresponds to a WBS element. As the system matures, the work and resource requirements are sufficiently well defined to use "bottoms up" techniques such as engineering estimates and actual costs obtained from prototypes and early production models. An engineering (production function) estimate would be based on the labor, material and overhead required to complete a particular element of the WBS. Obviously, this sort of estimation requires a great deal of information about how the system is built—data that is usually not available until the early phases of

production. Figure 2 shows the relationship between estimating techniques and the evolution of a system.
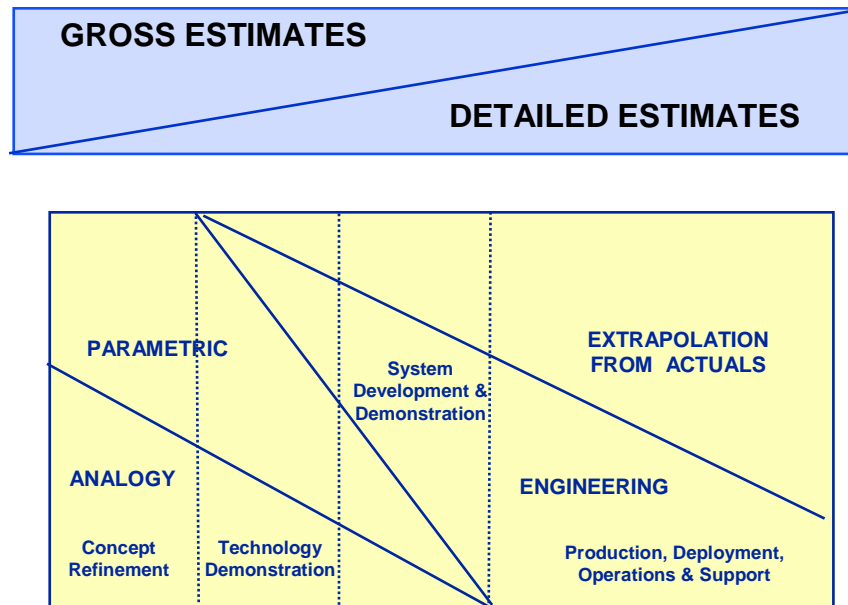
Figure 2. Cost Estimating Techniques as a Function of Acquisition Phases

While the WBS framework provides an excellent accounting system for cost estimates, it does have a few drawbacks. First, although it does capture the functional relationship between inputs/elements, it does not explicitly show the correlation between cost elements. If there is a correlation between cost elements that are assumed independent, this can significantly increase the variability of the cost estimate. Second, the program WBS, as defined by *Military Handbook 881A* , is input-oriented, not relationship-oriented; it, therefore, largely overlooks transaction costs such as search and information costs, decision and contracting costs, monitoring and enforcement costs. While it might be argued these costs are implicitly considered in the cost estimates of the various WBS components, it is likely that most are either underestimated or ignored, resulting in overly optimistic cost estimates.

V. A Brief Review of Transaction Cost Economics (TCE)

Transaction costs are typically faced by organizations dealing with outside suppliers. These include costs associated with: source selection, periodic competition and renegotiation, contract management, market structure, and measuring and monitoring performance. TCE emphasizes four key characteristics of transactions: *complexity*, *uncertainty*, *frequency*, and *asset specificity*. Transaction Cost Economics offers an attractive theoretical foundation for competitive sourcing decisions in the private sector (e.g., Coase, 1937; Williamson, 1971; 1979; Alchian & Demsetz, 1972). However, TCE has been less often applied in a government setting (e.g., Pint & Baldwin, 1997; Williamson, 1999; Franck & Melese, 2005; Dillard, Franck & Melese, 2006). An underlying objective of TCE (as a field of inquiry) is to improve the design of

contracts, organizations, and other governance structures that reduce transaction costs and improve the gains from exchange between buyers and sellers.

TCE predicts parties involved in a defense transaction can benefit from cooperation in the buyer-seller relationship and, thereby, generate a surplus that can be shared. For example, specific investments[14] made by either party that are of real value in the relationship (but perhaps of lesser value outside the relationship), can improve efficiency and effectiveness—yielding a surplus to be shared between the two parties. However, those parties often have conflicting interests; the DoD wants to maximize defense capabilities subject to budget constraints while Industry must concern itself with profits. Therefore, both sides have incentives to behave opportunistically, and may not necessarily have sufficient motivation to make investments that increase the parties' total gains. This is particularly true when specific assets are involved and information is imperfect and asymmetric. While defense acquisition focuses on production costs, it also exposes the organization to costs of managing the outsourcing relationship and to the risks of bad (opportunistic) behavior on the part of contracting partners.

Relationship-specific investments are potentially valuable, but can increase risks to both parties in a transaction. Having made a specialized investment, the supplier becomes the most efficient provider, and thus has an incentive to look for opportunities to extract more of the surplus (perhaps by demanding large increases in contract price to execute change orders). If a customer is "locked in," they may have little recourse. At some point, the relationship is transformed from a customer having the choice of a number of competing suppliers to a bi-lateral monopoly relationship between a single buyer and single seller. At this point, close-in bilateral bargaining replaces the impersonal (arms'-length) arrangements of the competitive marketplace.

This entails a *basic transformation* of the supplier from competitive bidder (prior to source selection) to monopoly supplier (after source selection), especially if there are no close substitutes for this particular contractor's products. Accordingly, the customer is now vulnerable to "opportunistic behavior"[15] from the contractor. Unforeseen circumstances combined with newly inelastic demand may prompt the supplier to extract more of the surplus created in the relationship.[16] The supplier can exploit its power in the relationship to renegotiate the basic agreement to its advantage, otherwise threatening to dissolve the agreement. The TCE literature refers to this as a "hold up."[17] This is one of the key insights TCE can offer to improve initial cost estimating.

If the supplier makes specific investments in assets that are only valuable in the context of the relationship with a specific customer, it is vulnerable to any changes in demand from that customer. Whereas relation-specific investments can increase the total gains from the defense

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[14] Asset specificity comes in a variety of forms, such as human, location and physical. These are specialized assets that generate high returns within a specific relationship, but offer little value outside it.

[15] Williamson, 1996, defines "opportunism" as "self-interest seeking with guile"

[16] Besanko, Williamson and others have labeled the transition from one prospective buyer and many sellers to one buyer and one seller, from competitive market to a one-on-one relationship, as the "fundamental transformation." This transformation occurs, at least to a certain extent, after the completion of every source-selection process.

[17] According to Besanko, "a hold up problem arises when a party in a contractual arrangement exploits the other party's vulnerability due to relationship-specific assets."

acquisition, they also increase risks of opportunistic behavior, through which either party can hold up the other. For example, either party can hold up the other by threatening to change the terms of the contract (relationship). The danger is that if neither party feels like it can recover the full costs of its investment in the relationship/transaction (say through a continuation or renewal of the contract), then efficiency-generating specific investments will not be made, resulting in higher (unanticipated) costs.[18]

A crucial insight of TCE is that different *ex ante* contracts offer different incentives for unproductive ex post bargaining and influence activities. As in game theory, it helps to look forward and reason back. If it appears managing the contract (including future competitions and/or renegotiations), and evaluating and monitoring performance, are likely to be costly (in terms of dollars or disputes, see Pigeon, 2006), then this should be taken into account in the original cost estimate, as well as in negotiating the optimal contract type. Table 1 provides a simple illustration of the spectrum of contract types that were awarded to the top 10 defense contractors over a six-year period.

Category	Cost-Plus (C+)	Fixed-Price (FP)	Time & Materials
1. Lockheed Martin	50%	47%	2%
2. Boeing Co.	27%	70%	2%
3. Raytheon Co.	38%	58%	3%
4. Northrop Grumman	42%	50%	2%
5. General Dynamics	39%	60%	0%
6. SAIC	52%	21%	15%
7. Carlyle Group	44%	46%	9%
8. Newport News Ship	78%	22%	0%
9. TRW	71%	23%	2%
10. Computer Sciences	41%	26%	24%

Table 1. Unclassified Details on the Type of Contracts Won by the Top 10 Contractors on Items Outsourced from 1998 to 2003 (Percent of Contracts Awarded that Were Cost-plus, Fixed-price and Time & Materials) (Makison, 2004)

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[18] Scope for opportunistic behavior may lead to adverse selection, choice of an (ex ante) inferior option (or technology), or moral hazard. Such scope increases risk that if a relationship-specific investment is made, the other party will exploit the terms of the contract to "hold them up." For example, changes in specifications are frequently used by contractors as a reason to raise prices and profits under government contracts, especially when those investments by the contractor create barriers to the entry of competitors.

The more complex and uncertain the transaction, the less complete the statement of work (performance work statement (PWS)), then the greater the cost in using FP, and the more attractive other contracting options become.[19] If the statement of work (PWS) describing the desired product, service or project can be specified precisely (IFB), and there are no transaction-specific assets involved, then FP type contracts have the benefit of creating cost-reducing incentives that reward the buyer through ex ante competition between potential suppliers. In this case, FP contracting increases contractor incentives to invest in cost reduction, and ex ante competition can transfer these cost-savings directly to the buyer.

In contrast, if the statement of work (PWS) cannot be specified precisely (RFP) or if there are significant specific assets involved in the transaction, then some surplus will be eroded by the frictions of ex post re-negotiation. This loss from unproductive bargaining activity is part of the cost of using a FP contract in this case. Initial cost estimates must take this into account.

Evidence uncovered by Bajari and Tadelis (1999) reveals that in cases in which a transaction is easy to define and measure (i.e., there is little complexity), and only a few minor changes are expected (i.e., there is little uncertainty), FP-type contracts tend to dominate. However, the more complex the transaction—the more difficult/costly it is to define and measure performance, and the more uncertain—the more likely it is a change in the contract will be required, the more severe the adversarial relationships experienced ex post when FP contracts are chosen. In the latter case, FP-type construction contracts often ended in costly renegotiations in which any surplus generated was dissipated in the course of those negotiations through unproductive bargaining and influence activities. Thus, *complexity* and *uncertainty* can force parties to turn away from FP type contracts and towards C+ type contracts, and to rely heavily on reputation and other enforcement mechanisms to avoid ex post opportunistic behavior that threatens to dissipate the surplus generated by a transaction.

FP (C+)-type contracts are usually prescribed in later (earlier) stages of product development when complexity and uncertainty have (have not) been resolved, and the performance work statement is well (not well) defined. Note that while these prescribed contracts focus on the characteristics of *complexity* and *uncertainty*, apparently overlooked are the vital roles of *frequency* and *asset specificity*—two key components of TCE.

In the case of *frequency*, recurrent transactions often justify the setup costs of specialized assets and special governance requirements. They also offer the opportunity to apply learning curves (cumulative cost-quantity relationships) to lower production costs, and for gradual reductions in uncertainty as both parties learn more about costs. Recurring transactions also offer the possibility for the accumulation of goodwill and to build reputations. Strategic partnerships and relation-specific investments can increase the benefits to both parties, but they

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[19] An example of the latter is Performance-based Logistics (PBL). The DoD defines PBL as: "an integrated acquisition and sustainment strategy for enhancing weapon system capability and readiness, where the contractual mechanisms […] include long-term relationships and appropriately structured incentives with service providers, both organic and non-organic [to] support the end user's (warfighter's) objectives." Any future investments in PBL could benefit from the multiple insights generated by TCE. The decision to outsource weapon system support or to bundle that support with an acquisition and to outsource the resulting bundle should weigh production cost savings against the costs and risks associated with a critical source of supply being outside the DoD's control. Those costs and risks are part of the transaction costs of outsourcing. TCE indicates outsourcing should only occur if there are positive net savings from the external supply relationship.

also leave them vulnerable to opportunistic behavior, or a hold up, by the other party. These vulnerabilities can be overcome with well-crafted contracts. However, contracting (a) involves an expenditure of resources, and (b) cannot eliminate all risks associated with opportunistic behavior from partners in the transaction.[20]

The interaction of opportunism with imperfect and asymmetric information raises the possibility of unproductive bargaining/influence or rent-seeking activities.[21] The ultimate outcome—a balance of productive efforts and unproductive bargaining—depends on the characteristics of the transaction, and the incentive structures that govern the parties involved, both of which should be factored into initial cost estimates.[22]

Where a transaction requires little in the way of specific assets (no hold up problem), and involves a product or service that is a) well-defined and homogeneous (IFB), b) easy to measure (limited complexity and mild information asymmetry), c) routinely used (recurring/frequent purchases), d) not subject to change (limited demand uncertainty), and e) is offered by competing suppliers, then there is little room for negotiation (price and performance are market-driven), and the marginal benefit of unproductive bargaining is near zero. With little room for bargaining over such routine and uncomplicated transactions, substantial production and transaction cost stability can be expected in the defense acquisition. Moreover, since administrative, incentive, and enforcement costs tend to be low for acquisitions in more contestable (competitive) markets, the marginal cost of engaging in the transaction is smaller for the DoD, and there exists an incentive for the supplier to invest in the transaction which generates opportunities for cost savings.

In general, the less complex and uncertain a transaction, the easier it is to write an explicit contract that covers all relevant contingencies. Moreover, the lower the administrative and enforcement costs of that contract, the lower the transaction costs associated with the contract. These favorable characteristics should encourage greater productive effort in the transaction relationship that, in turn, should contribute to lower costs and better products that

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[20] Costs associated with contracting and the holdup risks remaining are major components of "transactions costs." The process of contracting includes drafting the relevant documents, negotiating a version of the contract that is signed, taking actions to enforce that contract, and renegotiating when needed. These tasks entail, at minimum, the services of skilled people who develop local knowledge of the specific business relationship. There may also be costs associated with litigation, to include both direct (e.g., monetary) and indirect (e.g., time delay) components. Furthermore, the basic contract may well need considerable administrative and management attention throughout its life, even if full-scale renegotiation is not undertaken. Accomplishing these tasks satisfactorily involves expenditure of resources and management attention. Transaction costs (source selection, contract management and performance monitoring) can negate a significant portion of the production cost savings involved with outsourcing.

[21] The concept of unproductive bargaining and rent-seeking is usually attributed to Tullock (1971; 1993), Krueger (1974), and Bhagwati (1980). A key insight of this literature is that costly bilateral bargaining by two parties for a bigger share of the surplus they jointly create can dissipate or even eliminate that surplus (Tullock, 1971).

[22] There are other factors as well. For example, Wolff and Reed (2000) find significant evidence that, *inter alia*, the nature of, and access to, assets in a joint venture are important in predicting the balance of positive sum (productive) and zero sum (unproductive) outcomes for the participants.

benefit both parties. Identifying and understanding the characteristics of the transaction could result in more accurate initial cost estimates.

Alternatively, transactions that involve a non-standard (less homogeneous or highly differentiated) product often take place in a bilateral monopoly contractual setting. In this case, assuming no specific assets are required, the results depend on the degree of contractual ambiguity governing the transaction, as well as on any administrative and enforcement costs involved. However, as complexity, uncertainty, and opportunism due to specific investments increase, so does the marginal benefit of bargaining or ex post renegotiation. This results in both higher transaction costs to measure, monitor, and govern the relationship, as well as an increased risk of holdup.

Productive investment (or effort) involves two types of assets: general and specific. The greater the ratio of specific assets to total investments required in the relationship, the greater the risk of "holdup." Moreover, as the threat of bilateral dependency increases, the more incomplete the contract (and the lower the penalty for reneging or renegotiation), the lower the marginal cost to each party of engaging in unproductive bargaining or renegotiation.

In the face of incomplete contracting, the holdup problem poses a hazard called "maladaptation." The risk of maladaptation is captured here as an increase in the return to unproductive bargaining (for example, charging high prices for any change orders) or strategic renegotiation, both of which will increase costs from initial estimates. Any time ex ante competition among suppliers is transformed into an ex post, bilaterally dependent relationship, additional governance structures may be required to induce cooperative adaptation.[23] The challenge is to write a contract with enough precision to encourage desired performance, but enough flexibility to allow productive adaptation (adjustments), as circumstances require. But in the case of complex transactions and uncertain outcomes, "bounded rationality" precludes comprehensive ex ante contracting (contracts are inherently incomplete) which raises the possibility of gains from (unproductive) ex post opportunistic renegotiation (e.g., the "holdup" problem). Ideally, contracts can be written that specify measures of performance, conflict resolution procedures, and conditions under which the contract can be modified, as well as provisions for sharing gains from transaction-specific investments.[24]

In reality, contracting offers an imperfect solution to opportunism. Additional governance mechanisms to settle disputes and adapt to new conditions, ex ante efforts to screen for reliability, and provisions to protect transaction-specific investments may well ameliorate these problems. However, governance isn't costless, and such agreements often increase external transaction costs; and factoring those considerations into initial cost estimates may well improve their accuracy.

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[23] According to Williamson & Masten (1999), the "central problem of economic organization is adaptation" (p.xi). The challenge of adaptation is especially acute when ex ante competition leads to ex-post monopoly power. Whenever products, services or projects cannot be well specified in advance (due to complexity, uncertainty about future conditions, measurement difficulties, etc.), and they involve transaction-specific assets, then ex ante competition (e.g. competitive bidding) can lead to ex-post monopoly/monopsony power. In turn, this leads to costly adaptation through bilateral bargaining and renegotiation.

[24] The implications of this paper suggest that in the case of out-sourcing a transaction in which complexity, uncertainty and asset specificity can lead to renegotiation, the choice of governance structure will drive productive effort and unproductive bargaining.

Ashley & Workman (1986) caution that providing cost incentives in a contract can lead to disagreements and spoiled relationships and ex post friction in interpreting the outcomes. In fact, avoiding these frictions and reducing the advantages to renegotiation can be accomplished by investing in a more complete PWS, and by adopting alternative mechanisms (e.g., reputation effects, GOCO[25]) to reduce the return from opportunistic behavior. TCE suggests that the degree of completeness of the PWS and the contract is an optimizing decision by both parties that reflects their trade-offs between an ex ante investment in the PWS and contract design, and the potential ex post cost of opportunistic renegotiation.

A principal insight of TCE is that the choice of optimal governance structure depends on the characteristics of the transaction. Understanding these characteristics can improve initial cost estimates by: a) sorting transactions into categories based on their principal characteristics (uncertainty, complexity, asset specificity, contestability and frequency), and b) recognizing the costs and consequences of alternative contracts, organizational structures and mechanisms that are used to govern those transactions.

VI. Hypotheses: Possible Contributions of TCE

Our basic hypothesis is that including TCE considerations (currently an omitted variable) can improve cost-estimation methodology by (a) helping to explain the systematic bias observed in initial cost estimates, and (b) increasing the general explanatory power of cost estimations. That is, we assert the traditional WBS approach may overlook some important variables, resulting in initial cost estimates that are (a) not accurate and (b) biased toward being unrealistically low. More specifically, the TCE perspective suggests the traditional WBS approach indeed overlooks two important variables: Coordination Costs and Motivation Costs. Unlike the production function approach of WBS, the TCE approach focuses on these and other key components of major weapon system acquisitions.

However, once production starts, the contractor acquires specialized information and assets. Production is often subject to economies of scale and learning curves. The ability to shop around becomes restricted. Even though there may be contestability in the original design/development stage, bi-lateral monopoly arrangements emerge.

The system program office's functions/activities related to monitoring, controlling, information-gathering, reporting, decision reviews, enforcement, etc., grow as oversight/governance increases with anticipated scale and risk of investments. Though program cost data may exist, it does not tell us the whole story on transaction costs. Ideally, we would want to find total program costs and contract costs. The difference consists of transaction costs (whose main components are coordination and motivation costs).

Coordination Costs include: i) Search and Information Costs—to identify options and acquire timely, accurate and relevant information to evaluate alternatives; ii) Bargaining and Decision Costs—to choose an alternative and negotiate and write a contract; and iii) Policing and Enforcement Costs—to make payments and measure, monitor, and evaluate performance.

Motivation Costs include: i) Costs to promote productive effort and incentives to encourage investment (better, faster, cheaper) and ii) Costs to deter unproductive bargaining,

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[25] GOCO means "Government Owned, Contractor Operated" production assets.

and opportunistic behavior (renegotiation). Factoring TCE cost considerations into cost-estimating efforts could help the DoD anticipate cost increases in four key areas the GAO suggests help explain cost overruns:

a) constantly changing missions (uncertain demand/quantity/characteristics, bi-lateral monopoly, asset specificity, holdup, incomplete contracting);

b) yearly incremental funding vs. multi-year appropriations (uncertainty, frequency, asset specificity, holdup); program instability tends to discourage the investments that play a predominant role in moving costs down the learning curve (McNicol, 2005, p.26).

c) incentive problems (incomplete contracting, asset specificity, holdup); and

d) insufficient oversight (measurement, monitoring costs). (GAO, 1997)

A. Our Hypotheses in More Detail

The primary focus of this study is to see if insights from TCE can improve DoD cost-estimation/forecasting techniques. Our inquiry can conceptually be divided into three questions:

1. Is cost growth a problem?

    Ho: C $=$ Mean Cost Growth Factor = Actual Cost/Forecast Cost = 1

    H1: C > 1

2. Can cost-estimating models which include TCE insights improve estimated/forecast costs?

    Ho: TCE Factors (Complexity, Uncertainty, Asset Specificity, Frequency, etc.) do not matter—not significant in explaining cost growth.

    Ha: Alternatively, Forecast Cost = f (Production Costs; **Transaction Costs**), where Production Costs = g (WBS + systems integration),

    Transaction Costs =   Coordination Costs + Motivation Costs,

    Coordination Costs = g (Market Contestability Structure; Asset Specificity; Frequency; Search & Information tasks, Contracting & Enforcement functions, needed Management & Monitoring)

    Motivation Costs = h (Complexity; Uncertainty [of various kinds], Contract Type ...)

There is a fair amount of evidence about these hypotheses extant. In a sample of 52 systems, the GAO found that RDT&E costs for programs that started development with mature technologies (low complexity/uncertainty) increased by a modest average of around 5%, while those with immature technologies (high complexity/uncertainty) experience cost growth on average of almost 35%. Similarly, unit costs of procurement rose by less than 1% for programs with mature technology, whereas programs that started with immature technologies saw increases in unit costs of nearly 27% over initial estimates. As predicted by TCE, Complexity and Uncertainty combine to increase contractual hazards. If this is not adequately addressed in the contracting phase, then there is a greater likelihood of cost overruns.

B. The Case for the Null Hypotheses

Broadly stated, the null hypotheses state that incorporating TCE considerations into cost estimates will not significantly improve cost-estimating methodology. In the course of our research, we found a surprisingly persuasive case in favor of that proposition. There are, in fact, a number of reasons to be skeptical about our claim that transactions cost factors are important in determining costs of major acquisition programs. A number of plausible assertions (some related, some mutually exclusive) underlay such skepticism. While we find these assertions unpersuasive on balance, we cannot dismiss them out of hand.

1. *Asymetric Scope for Opportunistic Behavior in Defense Transactions*: It is more difficult to behave opportunistically when involved in a business relationship with a sovereign entity. In that case, the government has more scope for opportunistic behavior, with more of the attendant costs falling on the contractors. And, since the cost estimates we're considering refer primarily to the government's cost, adding TCE considerations considers only minor factors in those costs.

2. *Constancy of TCE factors*: Transactions costs are pretty much constant for all major acquisition programs.

   a. If (as asserted above) the government has more scope for opportunistic behavior, then prospective business partners will take that factor into account when considering whether to compete for government business—and build compensation for those risks into their bids. Furthermore, such risk premiums may be fairly constant across various types of projects, such as major acquisition programs.

   b. Every program includes an allowance for managing the contractual relationship (even though it's difficult to assign program management overhead completely to individual programs.) Possibly every program has enough of a management allowance to manage the program reasonably well. Put another way, the rule-of-thumb standard for program management permits individual program managers to deal with transactions difficulties well into the range of diminishing returns. Thus, even though transactions costs vary among programs, the standard program management allocation is sufficient to obscure those differences.

   c. Continuing with this line of reasoning, a variant of Parkinson's Law might apply. That is, for some programs the standard budget for program management is too much. However, program managers—perceiving (probably accurately)—that more program management activity has some marginal return, are strongly inclined to spend all their management budgets.

3. *Transactions Cost factors are already accounted for* in current cost-estimation methods. Measures of risk and complexity (such as technical-readiness indicators) indeed indicate the risk and complexity of the project. Also, however, the presence of those factors also offers increased scope for opportunistic behavior, and with it an increase in transactions cost. That is, the transactions cost elements in major program costs are highly correlated with variables already considered in standard cost-estimating methods.

4. *It all evens out.* Scope for opportunistic behavior cuts both ways. Scope for government opportunism increases (decreases) contractors' (government) costs while contractor

opportunism increases (decreases) government (contractors') costs. On average, it might well balance out.

5. While the effects of TCE considerations are important and a very significant factor in program costs, they're very *hard to find* (and quantify). By definition, opportunistic behavior involves guile (Williamson, 1996), and those who behave opportunistically have already taken pains to conceal their behavior (or assign other motives to it).

Therefore, while there is a persuasive case of the importance of TCE considerations in defense acquisition processes, it's not clear that one would be immediately led to conclude that incorporating TCE principles into cost-estimating models either (a) improves their explanatory power or (b) ameliorates the low-ball biases we observe in current practice. It comes down to a matter of resolving competing hypotheses with empirical data.

C. Testing Our Hypotheses

As shown in the sections above, our research has uncovered reasons to believe that TCE factors are important in DoD acquisition costs, but also that TCE insights may, in fact, not improve cost-estimation methodology. What's left is to sort out the competing claims using the available empirical evidence.

Our hypothesized set of relationships is depicted in Figure 3 below. To reject our null hypothesis, we need to do empirical tests, and have accordingly sought data on major DoD acquisition programs. For *Indicators of High Transactions Costs,* we apply the Powell (2002) stoplight scheme, with special emphasis on asset specificity. For *observable manifestations* of cost problems and governance issues *during the program*, we can consult histories of actual programs. In this report, we use case studies of actual Army acquisition programs compiled by one of our team members (John Dillard). These are reported in Section VII.
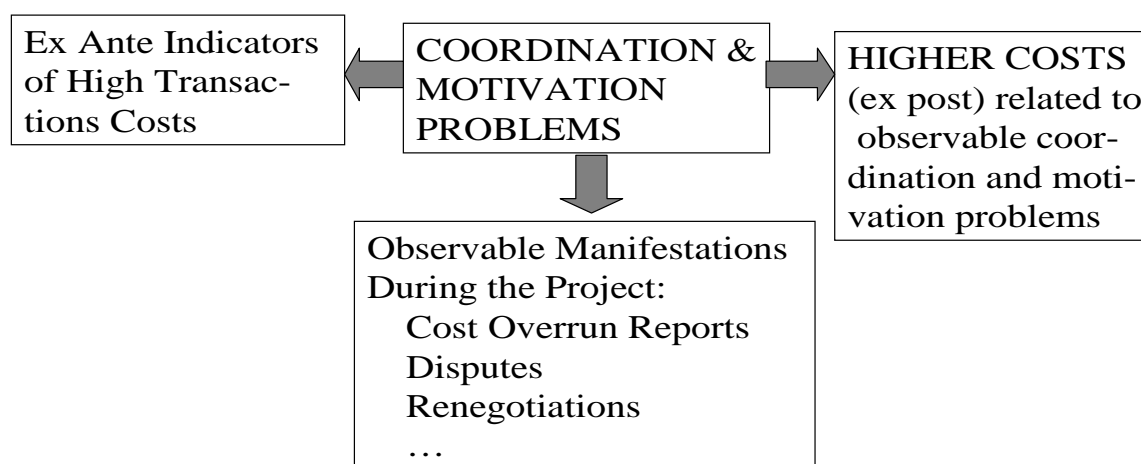
Figure 3. TCE Issues in Acquisition Projects and Hypothesized Cost Manifestations

We've also tracked Program Management Office costs as an indicator of actual transactions costs present within any given program. These are reported in Section VIII.

VII. TCE Applied to Two Defense Acquisition Case Studies

In the some of these authors' previous work (Dillard, Franck and Melese, 2006), fundamentals of transaction cost economics (TCE) were explained and insights from it were applied to defense acquisition. TCE asserts that "make-or-buy" decisions for the needs of a firm ultimately define its own vertical boundaries. And though much of the body of knowledge thus far consists of studies from the private sector, many public concerns engage in outsourcing as well. Defense acquisition is one such very large public enterprise and extends from R&D and procurement of materiel to purchasing services and sustaining support for its military forces. It is unique because, for the most part, the Department of Defense outsources much of what we consider to be "acquisition," commissioning external suppliers to develop products for its internal use, unlike many private and public organizations that conduct internal product development for themselves and others (or external products/services for others). TCE acknowledges that outsourcing relationships can vary widely in their transactional characteristics and can involve extra transaction costs such as measurement, monitoring, and negotiation costs that could negate the initially perceived advantages of the buy-versus-make decision.

TCE is descriptive of economic behavior and recognizes the issue of *motivation*. It assumes that economic actors, such as government acquiring "principals" and defense industry supplying "agents," are motivated to forecast potential outcomes and factor these into contracts. The DoD's general motivation (among, no doubt, other agendas) in its acquisition transactions is the seeking of better products, delivered quickly, and with fewest resources (i.e., performance, schedule, and cost). But such outsourcing is complicated by other phenomena. TCE characteristics of *complexity* (such as technology) and *uncertainty* (such as duration of work) apply clearly to many Defense acquisition transactions and lead to "incomplete contracting," termed as such from imperfect information and our inability to predict the future. These endanger a firm's ability to protect its own interest throughout the transaction, but hopefully are mitigated via governance mechanisms that positively influence a supplier's motivation to comply with the terms of an incomplete contract. These might be via contract incentives, enforcement mechanisms, monitoring methods, etc.

Another often encountered but heretofore largely unrecognized TCE characteristic (at least in Defense acquisition literature) is that of *asset specificity*—a situation in which a supplier "locks-in" the government by making investments in productive assets that are specific to the transaction and have little value elsewhere. Asset specificity can be related to physical capital equipment, human skills, facility location, and even brand equity (reputation). While needed to accomplish the work at hand, the result of these investments form barriers to competitive entry and can also result in a "holdup." A holdup is a problem that occurs when, for example, the agent in a contract has a specific asset with concerns that, after its investment, may have to accept worse terms than anticipated. Conversely, the principal has become increasingly dependent on the agent during his investment in the specific assets. It has become fairly typical in the DoD acquisition experience: with development contracts that are necessarily incomplete, sometimes won by low bids, and changes in contract scope later arise. The contractor can anticipate higher returns from "holding up" the government for such contract modifications. And while the government might have the sovereign right to terminate the contract for convenience, it will still be left with the demand for the product or service that was sought. Such has been the case in several programs observed by these authors, along with excursions into contract type and structure as options for obtaining desired outcomes.

Acquisition Case Examples

One of the authors was fortunate to have served as the Assistant Project Manager for Research & Development in two separate major defense acquisition programs that were offspring of Defense Advanced Research Projects Agency (DARPA) initiatives. These programs are described below to illustrate TCE challenges and uses of governance mechanisms.

The Javelin Project

The Advanced Anti-Armor Weapon System—Medium (AAWS-M), later to become the Javelin, began in 1982 as the DARPA program "Tank Breaker."[26] This was a one-year technology demonstration to explore various missile-guidance solutions for a medium range (i.e., 1-2000 meters) man-portable, anti-tank weapon. It was spawned as a result of deficiencies that were immediately apparent in the recently fielded DRAGON weapon system, which had replaced the M67 90mm recoilless rifle in the late 1970s. The DRAGON was a wire-guided, line-of-sight missile that was developed in response to the 1960s appearance of the Soviet AT-3 SAGGER, a manpack missile carried in a fiberglass "suitcase." In 1978, a Mission Need Statement highlighted deficiencies of the DRAGON, such as its poor reliability, limited range/lethality, and the difficulty for gunners to aim and track targets. The envisioned replacement was to satisfy a substantial increase in requirements—namely: range, lethality, reduced weight, and the ability to launch from enclosures (such as buildings or field-fortified bunkers). Several years were spent finalizing these requirements until the joint Army and Marine Corps operational requirements document was formally approved in 1986-88. A competitive fly-off program, which would now be called the "Technology Development phase," was conducted in 1987-1989 to select from three teams of contractors and critical technologies: a laser-beam rider led by Ford Aerospace, a fiber-optic guidance effort led by Hughes, and a forward-looking infrared (FLIR) thermal imaging sensor effort from Texas Instruments and Martin-Marietta. Clearly, the down-selection to one team was of great incentive to the participants, for it meant the likely follow-on award of the advanced development phase as well as production opportunities. Cost Plus Fixed Fee (CPFF) contracts were used with each of the three teams. Such is typical for "proof-of-principle" type R&D efforts in which knowledge work is risky for the contractor, and there are few discrete parameters to incentivize. All three teams were successful in flying missiles to their targets, but the only technology that enabled a true fire-and-forget capability (which was not a specified requirement) was the FLIR approach. Though this approach was recognized to be the most technically immature and risky, the desire for fire-and-forget survivability resulted in the FLIR team being awarded a contract for a three-year advanced-development phase.

In June of 1989, a full-scale development (now called System Development and Demonstration) contract was awarded for the Javelin program. The program was structured to encourage competition and give incentives for the accomplishment of all of the system objectives of the Department of Defense. First of all, the contract would be awarded to a team of two partnering firms that would combine their efforts for development of the system and split apart to compete during the production phase. The initial low-rate production was envisioned to be a competitive split awarded annually with a fifty/fifty or sixty/forty split between partners, via the use of fixed-price contracts. Such contracts are also typical for production efforts in which the design (uncertainty and complexity) is presumed to have evolved to a point of stability. At

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[26] DTIC reports summarizing this DARPA effort are available at http://stinet.dtic.mil/oai/oai?&verb=getRecord&metadataPrefix=html&identifier=ADA122234.

the macro level, the office of the Secretary of Defense viewed the program as acceptable with regard to risk because of its 27-month technology development phase and subsequent 36-month plan for full-scale development.

During the technology-development phase, all three contractor teams had scored over 62% hits with at least ten missile shots each in a variety of environments and operational settings. The full-scale development contract request for proposal was written for a cost-plus-incentive-fee type of contract, but the winning proposal was presented with a "no-fee" bid. This surprised the Government, which nevertheless awarded a cost-plus-incentive-fee contract, giving incentives for key performance parameters such as weight and warhead performance that it considered technically risky. The total value of the contract was $169.7 million, the amount bid by the winning team of Texas Instruments and Martin-Marietta. Meanwhile, the Government privately conducted its own should-cost estimate and budgeted $263 million for the 36-month long development effort. In addition, the Government ran its own alternate warhead technology development program with CMS acting as the contractor.

The two-partner Joint Venture in full-scale development was also free to maximize competition at the subcontractor level. In their make-versus-buy decision, Texas Instruments elected to make the focal plane array for both of its uses in the command launch unit and in the missile. They had made these devises for other programs but not in these two distinct configurations. Their physical-specific assets were located at the manufacturing facility in Lewisville, Texas, largely for the promise of the Javelin system's later production. They had expanded that facility for the Javelin program in anticipation of producing some 58,000 to 70,000 missiles and 5,000 command launch units (the thermal imaging sighting device).

Each missile focal plane array was forecasted to be approximately 15% of the missile's cost (or about $12,000 for each of the focal plane arrays) based upon a $90,000 "cost per kill" program objective. Focal plane array technology was still immature and would be gauged today at approximately technology readiness level five (on a 1-9 scale), despite its successful technology development phase results. It was always recognized as technologically risky, so the Government partially funded other companies that could produce these devices. In 1991, the only five known FPA makers in the world were Rockwell International, Loral, Santa Barbara Research Corporation, Sofradir (a French firm), and Texas Instruments.

As an additional gauge of technological maturity, a baseline test was mandated at the second milestone upon the decision to launch the Javelin program into full-scale development. That test would pit the immature focal plane array technology against existing TOW and DRAGON (legacy systems) missile optics. Results of this test showed the Javelin's immature focal plane arrays to be substantially better in performance than the DRAGON and almost as good or as good as the larger TOW anti-tank missile system.

Approximately 18 months after the full-scale development phase contract award, the Javelin project manager called for Defense Acquisition Board, forecasting a Nunn-McCurdy breach of cost and scheduling thresholds in this ACAT 1-D program. Several reasons were cited, not the least of which was that the focal plane array production yield was not as predicted—and all of the devices were below specification. The cost growth was found throughout the various elements of the project, as illustrated in Table 2 below.

Over the next year, the program was given a new baseline with many different revised program estimates climbing from 36 months duration and $298 million in cost, to 48 months duration and $372 million in cost, and then to 54 months and $420 million for the total cost and

duration of this phase. In addition to the rebaselining, the Government renegotiated its cost-plus-incentive-fee contract with the joint venture and established cost sharing for any expenditure above $372 million, all the way to the contract ceiling of $420 million.

This was a very unique move, to re-establish governance mechanisms in the middle of a transaction. But the contractor's "failure to perform," although in an uncertain R&D environment, justified the new relationship. At 30 months after contract award, the program was finally formally re-baselined to be 54 months and $443 million, with 50/50 JV and Government cost-sharing ratio above that amount.

In October of 1991 at a meeting in the Lewisville, Texas, focal plane array manufacturing facility, the "divorce" finally came for TI as prime vendor of the missile focal plane array. Texas Instruments had failed to achieve specification for the item by the target date, but they still had a stake in the program as one of the principal players on the joint venture team.

About this same time, the Government discovered a focal plane array "holding account" that had been proposed and was awarded in scope of the contract. Essentially, this holding account accrued charges to the Government for every non-specification compliant focal plane array that TI had produced. The cumulative total was to be billed all at once, when they achieved the first specification-compliant focal plane array.

AAWS-M
CONTRACT COST GROWTH
(JUN 89 TO PRESENT)

	ORIGINAL BUDGET	CURRENT LRE	DELTA
1. ROUND & MISSILE	11,733	20,048	(8,315)
2. PROPULSION	2,327	8,386	(6,059)
3. WARHEAD/CONTACT FUZE	9,720	13,661	(3,941)
4. ELECTRONIC SAFE AND FIRE	1,459	6,926	(5,467)
5. GUIDANCE SECTION	16,092	35,662	(19,570)
6. SEEKER	24,227	47,905	(23,678)
INCLUDES FOCAL PLANE ARRAY	[14,000]	[33,000]	[19,000]
7. CONTROL ACTUATION SYSTEM	2,046	5,180	(3,134)
8. TELEMETRY	2,405	4,085	(1,680)
9. LAUNCH TUBE ASSEMBLY	2,036	6,583	(4,547)
10. BATTERY COOLANT UNIT	1,155	4,849	(3,694)
11. ROUND SHIPPING CONTAINER	107	2,420	(2,313)
12. COMMAND LAUNCH UNIT	18,976	53,812	(34,836)
INCLUDES DETECTOR DEWAR COOLER	[2,600]	[15,100]	[12,500]
13. TRAINING DEVICES	7,755	9,636	(1,881)
14. TEST & EVALUATION	11,260	12,510	(1,250)
15. SYSTEM ENGINEERING	9,362	21,606	(12,244)
16. PROJECT MANAGEMENT	35,298	64,596	(29,298)
17. INTEGRATED LOGISTICS SUPPORT	3,949	6,070	(2,121)
18. DATA	4,026	4,505	(479)
19. JOINT VENTURE G&A	11,591	20,247	(8,656)
ALL OTHER	4,559	13,465	(8,906)
TOTAL	180,083*	362,152	(182,069)

*$169.7M + CONTRACT MODS

Table 2. Early 1991 Summary of Javelin Program Component Cost Growth

Since the contract was cost-reimbursable in form, the Government was likely to have to pay for all costs of development regardless of spec compliance, but the way the billing transpired took the Government by surprise. Fortunately, dual sourcing of critical components is

a fundamental element in acquisition strategy development and risk mitigation. And the selection of Hughes's Santa Barbara Research Corporation as a sub-contractor to the other Joint Venture partner, Martin-Marietta, saved the Javelin program. That small company had discovered a process to produce near-perfect focal plane arrays repeatably, and they were accelerated to provide these for the program. The investment was, in hindsight, a "real option" that was exercised mid-project with great return on investment.

Within that year, the program was restructured, given the new baseline, and finished largely within its new parameters. The additional 18 months added to the 36-month phase helped resolve the uncertainties and complexities of system development without additional schedule slippage. Later, production quantities were slashed in half as the Defense Department drew down its forces from 1991-2000, and the acquisition strategy to split apart the joint venture and compete them in production was not fulfilled. Benefits of a split production no longer able to be realized, the JV remained intact as the producing entity. Today Javelin is seen as a successful weapon system, is being used in Iraq and Afghanistan and has been through several full-rate production contract periods.

The Army Tactical Missile System Project

The Army Tactical Missile System also started out as a DARPA program, called Assault Breaker, in the 1970s. The system's prime contractor for the vehicle, the Multiple Launch Rocket System, or MLRS, was LTV Corporation. With significant asset specificity from their platform efforts (and physical & knowledge capital), they bid upon and won two separate contracts for the Army Tactical Missile System. These were both firm-fixed-price: one for the invention of the missile and one for its integration into the platform. The program was a 48-month full-scale development effort that was begun in 1986 and ended in 1990. In stark contrast to the Javelin program, fixed-price contracts were deemed appropriate to this transaction because of the technology maturity in the ATACMS project, relative to most others, where CPIF contracts are common—as depicted in Table 3.

Key Program Characteristics - First Increment of Capability

Program Aspects	ATACMS	JAVELIN
DARPA Predecessor	Assault Breaker 1977-82	Tank Breaker 1981-82
Ultimate Capability	*"Deep Attack"*	*"Fire & Forget"*
Critical Technologies & Readiness Levels:		
Munition	9 - Lance M74 Bomblet	5 - Tandem Shaped Charges
Propulsion	9 - Solid Rocket Motor	5 - Two-Stage Solid Rocket Motor
Flight Control	9 - Fin surfaces	6 - Fins + Thrust Vector Control Vanes
Guidance and Control	9 - Inertial	4 - Tracker Software Algorithm
Safe/Arm Fusing	7 - Mechanical	4 - Electronic
Software Function (Target Acquisition, Fire Control, etc.)	6 - Various	6 - Various
Sensor	N/A	5 - Focal Plane Array
Capability Leap Area	Range	Range, Lethality, Survivability
Cost of development	~$700M	~$700M
Contract Type	Fixed Price	Cost Reimbursable
Tech Development Phase	0 Months	27 Months
Advanced Development Phase - Planned	48 Months	36 Months
Advanced Development Phase - Actual	51 Months	54 Months
Total Time in Development	51 Months	81 Months
Advanced Development Phase Contract Cost Growth	0%	>150%

Table 3. Comparison of Programs Using Different Contract Types and Technology Readiness Levels

Also, this program was structured to have production options, should the full-scale development phase be successful. Thus, there were incentives for "performance" on both the Government and the contractor side: LTV was given an incentive to succeed in the development of the missile and its integration in order to win the follow-on low- and full-rate production contracts. And likewise, the Government had an "incentive" to conduct reviews and make decisions to award production by November of 1990. This was to preserve production-pricing options that the contractor had been asked to provide in his proposal for advanced development. The price reduction from these options, if exercised before expiration, was on the order of 40%. As it turned out, the production options were exercised within a week of their expiration, saving the Government several hundred thousand dollars per missile on the eve of the first Persian Gulf War.

These cases may only serve to illustrate several recognized economic behaviors within the context of large acquisition transactions. As an adjunct to our earlier work (Dillard, Franck & Melese, 2006), they show how complexity and uncertainty of development projects relate to contract type and governance mechanisms. Importantly, they also convey the need to constrain scope in order to control cost and schedule. In and of themselves, they cannot necessarily prove cause and effect, but rather reveal the importance of understanding key characteristics of a transaction early in the cost-estimation process in order to capture relevant transaction cost elements that can impact the ultimate price paid for major weapon systems.

TCE Assessment of the Case Studies

As indicated in Section VI above, we looked for observable effects of TCE factors in actual DoD acquisition programs. This section analyzes the two cases (Javelin and ATACMS) described above in terms of: (1) ex ante indicators of transactions costs, (2) manifestations of motivation and coordination problems in the course of the program, and (3) cost overruns observable at program completion.

The ex ante indicators come from a scheme proposed by Powell (2002) and augmented by Franck (2004). The indicators of transaction costs considered here are asset specificity, complexity, length of the relationship (or transaction), time sensitivity of performance, and operational significance of performance.

TCE Indicator	Assessment	Comments
Asset Specificity	YELLOW	TI's insourcing of FPA production. Mitigated by planned dual-source production, and steps to diversify FPA sources.
Complexity	RED	Fire-and-forget feature added significantly to complexity.
Length of Relationship	YELLOW	Technical immaturity necessitated a lengthy development program.
Time Sensitivity	YELLOW	Green after end of Cold War.
Operational Significance	YELLOW	Green after end of Cold War

Table 4. Ex Ante Assessment of Javelin Development Program

TCE Indicator	Assessment	Comments
Asset Specificity	RED	Pre-existing condition. Contractor's previous experience with launch vehicle. Production option proved a hedge for the contractor.
Complexity	GREEN	Technology generally mature
Length of Relationship	GREEN	Advanced Development Phase only.
Time Sensitivity	YELLOW	Green after end of Cold War
Operational Significance	YELLOW	Green after end of Cold War

Table 5. Ex Ante Assessment of ATACMS Development Program
(Powell (2002), Franck (2004) and authors' assessments)

The relative immaturity of Javelin technologies necessitated a long and complex transaction. Worth noting is that a government decision, in favor of the fire-and-forget feature, increased these difficulties.[27] By contrast, the ATACMS development program was based largely on proven technologies. For both development programs, Time Sensitivity and Operational Significance decreased considerably with the end of the Cold War. Both ATACMS and Javelin were designed to counter massive Warsaw Pact mechanized offensives, at the

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[27] We have no basis to question (from an ex ante perspective) the Army's decision to opt for a less mature technology in pursuit of significantly higher performance. However, we believe consideration of the increase in scope for opportunistic behavior in the program should be considered when making such decisions.

operational and tactical levels respectively. With the end of the Cold War, both priority (operational significance) and urgency (time sensitivity) lessened accordingly. Arguably, this development significantly strengthened the government's position in the negotiations associated with governance of both programs.

Observable manifestations of motivation and coordination difficulties during the course of the project are gleaned from the narratives above. For Javelin, there were a number of difficulties apparent throughout the problem, predictable from a TCE perspective. These included the following.

- The winning bid clearly seems to have been a buy-in. The contracting team's initial estimate was significantly below the government's estimate of most likely program cost. From a TCE perspective, this can be interpreted as setting the stage for opportunistic behavior on behalf of the contractors.

- One member (Texas Instruments) of the development team (the Joint Venture) chose to make the Focal Plane Arrays (FPAs) within firm boundaries. The FPAs were arguably the critical, and pacing, element of the Javelin development program. Whether this indicates opportunistic behavior by TI, or simply a miscalculation, is difficult to assess. Worth noting, however, is that the Army took steps toward developing an alternate source. A TCE perspective would indicate the government perceived some scope for opportunistic behavior; a risk-management perspective would interpret this as a risk reduction measure.

- There was steady, and cumulatively very significant, cost growth throughout the program. As a result, the Program Manager reported breaches of criteria for both cost and schedule—relatively early during the program.

- Other cost-growth problems appeared. For example, the bill for FPA's not meeting specifications was presented to the government without previous notice. This turned out to be an unpleasant surprise. Whether this was simply a communications difficulty or opportunistic behavior on the part of the Joint Venture is not clear.

- Consequently, governance of the transaction became significantly more complicated. Major changes to program structure were negotiated as part of a "re-baselining." Additionally, the contract's incentive structure was changed— from a cost-plus to a risk-sharing form.

Overall, there was significant cost growth (over 150%) in the Javelin development program.

For ATACMS, the only major indicator of transactions cost-related difficulties was asset specificity. LTV's previous experience with the launch vehicle (the MLRS) gave it a substantial advantage over alternate vendors—making this an excellent example of what can happen with asset specificity. However, the program was executed on schedule and within the original cost estimate. It's possible that LTV had no incentive to low-ball its original estimate with its already significant advantages over potential competitors based on asset specificity.

There was arguably evidence of opportunistic behavior on the part of the government.

- A program based on a fixed-price contract was extended by three months (from 48 to 51) simply because of governmental convenience—without compensation to the contractor.

- Also, the government was slow to exercise its option to order the start of production, and would likely have delayed its decision further were it not for the imminent expiration of a favorable price option in the contract. It's reasonable to suppose that this part of the contract served to head off opportunistic behavior on the part of the government.

Some observations are useful at this point. First, the indicators of high transactions costs should be considered *in toto*. As we've stated above, there are excellent reasons to believe that asset specificity is particularly important in creating conditions for opportunistic behavior in a transaction. However, in the case of ATACMS, there appears to have been no bad behavior that added significantly to program outcomes (cost, schedule or performance), despite the RED assessment for asset specificity.

Second, opportunistic behavior in transactions is a question of motives, and it's difficult to sort out motives in case narratives. For example, was the contractors' original estimate for Javelin development a buy-in or a manifestation of the Winner's Curse? Was the unexpected presentation of the bill for substandard Javelin FPAs a matter of opportunistic behavior (self-interest seeking with guile) or simply an administrative failure to communicate? Without considerably more information that's available in the public record, it's difficult to sort out such matters.[28]

However, finally, there is good evidence that TCE perspectives offer significant explanatory power in analyzing program outcomes—including cost. Based on this sample of two, however, it's explanation of the qualitative sort. Our next section (VIII) explores quantitative evidence of transactions costs at a macro level.

VIII. Program Office Costs and TCE

In order to test our hypothesis that the traditional WBS approach may overlook some important variables resulting in unrealistically low initial cost estimates, we would have to compare cost estimates for systems that included significant transaction costs with those of systems that did not include significant transaction costs. The first problem, then, was to find a way to measure transaction costs in acquisition programs. We proposed using Program Management Office (PMO) costs as a proxy measure of the amount of transaction costs present in an acquisition program.

We started by examining information from the Consolidated Acquisition Reporting System (CARS) to find evidence of transaction costs. The information is contained in the Defense Acquisition University (DAU) Business Information Laboratory (BIL) database managed by OUSD(AT&L) Acquisition Resources and Analysis. It includes information on contract performance and program cost from a variety of reports, such as Selected Acquisition Reports (SAR) and Defense Acquisition Executive Summaries (DAES), as well as other reports. Unfortunately, these reports do not contain the level of detail necessary to identify transaction costs. Specifically, there was no information on the amount of resources estimated or used for the PMO.

Instead, we looked at the Budget Item Justification sheets in the OSD budget (http://www.defenselink.mil/comptroller/budgetindex.html). While there is some information on PMO costs in these documents, it is reported inconsistently or not at all (depending on the

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[28] The obvious incentives to conceal the motives underlying self-seeking behavior add to this difficulty.

program and year). For example, the Marine Corps Advanced Amphibious Assault Vehicle (AAAV)[29] reported Program Office costs in exhibit R-3 under "Support and Management Organizations" for FY97 and FY98, but discontinued reporting that line-item in subsequent years. Note also that what is included in PMO costs is not a complete picture of the resources used, since military salaries are excluded and civilian salaries may or may not be included depending on how they are funded.

The AAAV reported costs for the more general category "Support and Management" for FY97 – FY06, but the line-items included in this category varied from year to year. If we expand our proxy measure to the "Support and Management" category, we are including, in addition to Program Office costs, other support contracts, miscellaneous contracts and government labs, as well as modeling and simulation. As the program developed, this category grew to include integrated logistics support, training devices and simulators, tech data and publications development and support equipment development. Clearly, this category includes costs that should not be considered transaction costs, such as training devices and simulators and tech data and publications. More importantly, what is and is not included in the category varies over time, making the identification of transaction costs difficult on a case-by-case basis and nearly impossible on a large scale.

A more significant problem we encountered is that the information reported in CARS does not necessarily track to the information reported for the same program in the OSD budget. This problem was confirmed by OUSD(AT&L) Acquisition Resources and Analysis and is an issue they have been working on for over 3 years and have documented in a *Comparison Report* that identifies potential FY07 funding disconnects between the OUSD(Comptroller) Budget Justification Materials and the OUSD(AT&L) Draft Selected Acquisition Reports.

Contributing to the difficulty of identifying program transaction costs is the fact that program managers only report information on a program's major contracts for RDT&E, procurement, military construction, and acquisition-related operation and maintenance. According to the CARS *Users' Guide*, SAR Section 15 (Contract Information) only includes the six largest, currently active contracts (excludes subcontracts) that exceed $40 million in then-year dollars. For a given reporting quarter, these are generally the same contracts reporting in Section 6 (Program Background Data) of the DAES. If a previously reported contract is over 90% complete, it will no longer be reported. So, tracking Budget at Completion (BAC) and Estimate at Completion (EAC) at the program level involves moving targets as the individual contracts are completed and drop out of the CARS. Also, the total amount shown for the program in the OSD budget may include other contracts not reported in CARS.

Due to the data difficulties described above, we were unable to test our first hypothesis using our selected proxy measure for transaction costs. In fact, it seems measuring transaction costs directly or by proxy from the existing data bases may not be possible.

As an alternative, we could always infer that differences due to complexity or technology maturity imply higher transaction costs and use this categorization to compare programs with assumed high transaction costs to programs with assumed low transaction costs. For example, Brown, Flowe and Hamel define transaction costs as costs associated with interdependent activities, and they suggest that joint programs (involving two or more services) would have higher transaction costs than single-service programs. Certainly, the coordination costs could

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[29] The name of this program changed to Expeditionary Fighting Vehicle (EFV) in FY03.

be assumed to be higher for joint programs. When they examined 84 DoD weapon system programs (45 joint and 39 single) in terms of number and type of programmatic breaches, they found that joint programs were statistically more likely to experience breaches in schedule, research development testing and evaluation costs and unit costs. If we assume joint programs have higher transactions costs, then their findings may suggest that programs with higher transactions costs require distinct measures and metrics to improve cost and schedule estimates.

IX. Summary and Policy Recommendations

Developing accurate cost forecasts is essential for future budgeting and to improving defense decision-making. This paper has documented a growing body of evidence of a systematic downward bias in initial cost estimates for major weapon systems. An important consequence of these forecasting difficulties is that "major weapon systems […] are experiencing recurring problems with cost overruns, missed deadlines, and performance shortfalls" (GAO, 2006, March, p.1). Runaway costs threaten to weaken the armed forces. Cash-flow shortfalls lead to quantity reductions, reprogramming, and funding reductions for other programs. These cost increases mean that the DoD cannot produce as many weapons as intended nor deliver those weapons to the warfighter when promised. Cost overruns squeeze existing and competing programs. Higher price tags mean that fewer of those weapons end up in the hands of soldiers, and that options on new weapons cannot be exercised without breaking the budget.

Two factors are usually blamed for unrealistically low cost forecasts: bad incentives (psychological and political-economic explanations) and bad estimates (methodological explanations). The focus of this paper is on cost methodology. The case studies suggest that inclusion of transaction costs as a recognized component of total cost adds to explanatory and forecasting power of cost-estimation methods. However, we also found that current data bases are not well structured for identifying the transaction costs of major acquisition programs—for a number of reasons.

What can be done to reduce actual costs/expenditures? TCE suggests identifying strategies to cut coordination and motivation costs. Specific recommendations to cut Coordination and Motivation Costs would include the following:

a. Reducing Complexity: Investing in a more complete contract (increasing search and information costs) and the use of more mature technologies.

b. Reducing Uncertainty through multi-year contracts (demand uncertainty); investing in more complete contracts (relationship uncertainty).

c. Increasing measurement and monitoring to reduce information asymmetries (and associated risks).

d. Putting credible deterrents to bad behavior in place—such as penalty clauses, warranties and bonding; using multi-year contracts to gather information and reward good reputations.

e. Mitigating the uncertainties introduced by asset specificity through careful use of incentives, proper bundling of goods and services and GOCO assets.

f. Increasing contestability of government contracts through government-controlled standby capacity (threat of vertical integration), second sourcing, and preservation of real options (threat of entry of competing suppliers).

That said, however, the primary insight drawn from TCE is that correctly estimating production costs is necessary, but not sufficient. The choice of contract, organization, and incentives—along with key characteristics of markets and transactions (uncertainty, complexity, asset specificity, frequency, and contestability)—must be included to obtain reliable cost estimates. Leveraging TCE in this way could help characterize, explain, forecast, and ultimately reduce the cost growth that plagues many of today's major investments in military capabilities.

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Managing Uncertainty and Risk in Public-sector Investments

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Introduction

The Department of Defense (DoD) has an annual budget approaching a half trillion dollars. A significant portion of that budget is either directly or indirectly affected by Information Technology (IT) Infrastructure modernization initiatives. Nationally, investment in IT infrastructure modernization is about $250 Billion a year, spanning approximately 175,000 projects. Unfortunately, various studies indicate that only 28% are completed on time and on budget—with the number dropping to around 9% for larger companies in 1994, including government programs. By 1998, these numbers had improved, with success rates for larger companies, for example, up to 24%. But, only small organizations have managed to implement more than half of their applications into one integrated system (Smith, 2000; Johnson, 1999, December; Keller, 2006, May 29).

The factors driving these numbers are myriad—and include the sheer scope and complexity of infrastructure modernization programs, unstable/undefined requirements, unstable funding, moving target objectives, and evolving threats. As a result, the costs of integration complexity increase exponentially, but yet are almost invariably under estimated. These challenges notwithstanding, one Gartner study asserts that IT asset productivity will drive market capitalization (Gartner, 2002, July).

Given the scope, importance and complexity of these projects, reliable, cost-effective, early warning indicators of problems are essential. Yet, classical investment theory provides little guidance for dealing with public-sector investment. The result is a general absence of computationally efficient, predictive models applicable to the analysis of those investments.

However, there is progress on several fronts. At the micro level, Earned Value Management is gaining acceptance. But, more comprehensive, flexible methods can be developed by viewing a Firm as an engineered artifact whose responses to a range of inputs can be characterized in terms of duration, mass, time, stability, and location. (By way of terminology, a "Firm" refers to both public and private organizations with investment responsibilities.)

How well a Firm executes an investment depends largely on how well it acquires and uses information. The efficiency of that use provides a basis for pricing the value of a Firm, independent of valuations derived from equity markets.

For the private sector, Capital Asset Pricing Models (CAPM) models provide valuation tools, of which the Black-Scholes equation is the most well known and successful example. These models are based on the observation that equity markets have properties that can be analyzed using models based on the "Law of Large Numbers."

Unfortunately, the conditions enabling the quantitative analysis of private-sector investments do not apply in the public sector because there is no market for public-sector goods. Nonetheless, all Firms, regardless of whether they are in the private or public sector, must respond to a range of random (external and internal) perturbations. The responses can be accurately modeled using mathematical processes based on the "Law of Large Numbers." In particular, the operation of a Firm can be modeled as a stochastic feedback system using algorithms from Information Theory and System Control Theory.

IT Infrastructure Investments—in the Public Sector

Private equity markets provide a profit incentive to resolve uncertainty, which has as one of its effects the rapid aggregation of information from large numbers of participants. In general, the larger and more diverse the number of sources, the more accurate is a Firm's valuation. (With the Web and the Internet dramatically lowering the cost of information, similar aggregation effects are occurring in the news media, entertainment, and politics, as evidenced by the impact of Napster, U-Tube, Google, etc.)

Unfortunately, the Public Sector lacks an incentive mechanism and usually consists of a few service/product providers, and generally only one customer—the government. (Markets with few sellers and buyers are more suited to analysis by Game Theory.)

Despite these differences, private and public sectors share a range of common concerns, especially for large scale IT modernization projects. Among these is a compelling need to answer questions such as:

- What level of uncertainty surrounds cost/schedule estimates, especially at the onset of a major investment in IT infra-structure?

- Under what conditions will risk/uncertainty decline or rise? And at what rate?

- How can risk/uncertainty concerning cost, schedule, and scope be identified in a timely manner, quantified, and mitigated?

- How can a Firm best respond to disruptions to supply, budget and schedule or to the introduction of new technologies by competitors?

- At what point in a project-development cycle will estimates of cost, schedule, and scope become both stable and credible?

- How can confidence levels in cost and schedule estimates be measured?

- Are project requirements under active management sufficiently stable to ensure project completion on time and within budget?

- What (quantitative) models can be used to determine the maximum effective rate of investment for public-sector projects?

- How can an optimal investment portfolio be constructed?

- And, how is such a portfolio optimality measured?

- How do the performance measures such as requirements stability, work package completion, rework rates and resolution rates for major and minor issues correlate with each other?

- Is there a level of disruption or tipping point to the schedule, cost, and resource allocations beyond which a project cannot recover?

Developing a quantitative framework capable of answering these questions is the objective of the paper. The strategy is to employ key parameters governing the efficiency of a Firm's operation in terms of observable, easy-to-compute variables in mathematical models of the underlying process dynamics.

Portfolio Investment Management—An Overview

Large-scale Defense infrastructure modernization programs such as Global Combat Support have complex inter-dependencies and long-time horizons that render fully informed investment decisions difficult to achieve before substantial, and unrecoverable, resources are committed. However complex these decisions, they, nonetheless, can be decomposed along three basic dimensions:

- Uncertainty

- Timing

- Irreversibility

These primary parameters define the value of investment options available to a Firm, regardless of whether it is in the public or private sector. Unfortunately, algorithms capable of modeling the effects of these variables are relatively few, especially for the uncertainty and irreversibility of investment decisions (Dixit & Pyndik, 1994, p. 211). For large-scale Information Technology (IT) modernization programs, there are at least three sources of uncertainty—and, thus, risk

- The technical complexity

- The programmatic complexity of integrating software intensive systems

- The absence of accurate cost information at the onset of major systems/ software programs

Software-intensive systems are particularly sensitive to the systematic under-estimation of risk, primarily because the level of complexity is hard to manage, let alone comprehend. Investment in software-intensive systems tends to be irreversible because it is spent on the labor required to develop the intellectual capital embedded in software.

The outcome of software development is almost invariably unique, a one-of-a-kind artifact—despite the numerous efforts to develop reusable software. Unlike physical assets, the salvage value of software is zero because no benefit is realized until the system is deployed; and that labor, once invested, is unrecoverable. One result is an (implicit) incentive to continue projects that have little chance of success, despite significant cost overruns, schedule delays.

Indeed, an analysis of several hundred NASA projects indicates that accurate estimates at project onset are virtually impossible to achieve, which raises concern for the validity of initial Planned Value estimates since they are the basis of Earned Value

calculations (Suter, 2005, p. 261). Thus, measures of uncertainty for cost/schedule estimates and the rate at which that uncertainty declines are a key concern—because, they govern whether and to what extent confidence can be placed in cost and schedule estimates. The key to overcoming initial estimate uncertainty is the capability to harness and to apply information as it becomes available, thus, enabling a Firm to capture the time value of that information.

Indeed, where IT infrastructure modernization projects are supported by a strong quality-assurance, systems-engineering culture (e.g., have institutionalized best-practice regimes such as the CMMI, 6-Sigma, Agile Methods) are likely to quickly reduce estimate errors incurred at project start-up. Firms without that culture tend to have limited information efficiency. (Drawing an analogy to thermo-dynamic systems, such Firms constitute highly dissipative systems in that they exhibit a high degree of entropy, which takes the form of information disorganization).

Unfortunately, traditional methods of discounting investment risk such as Net Present Value (NPV) do not account for irreversibility and uncertainty. In part, this is due to the fact that NPV computes the value of a portfolio of investments as the maximized mean of discounted cash flows on the assumption that the risk to underlying investment options can be replicated by assets in a financial market.

NPV also implicitly assumes that the value of the underlying asset is known and accurate at the time the investment decision is made.

These assumptions seldom apply for large-scale infra-modernization programs, in either the public or the private sector. In addition, NPV investment is undertaken when the value of a unit of capital is at least as large as its purchase and installation costs. But, this can be error prone since opportunity costs are highly sensitive to the uncertainty surrounding the future value of the project due to factors such as the riskiness of future cash flows. These considerations also extend to econometric models, which exclude irreversibility, the incorporation of which transforms investment models into non-linear equations (Dixit & Pindyck, 1994, p. 421). Nonetheless, irreversibility constitutes both a negative opportunity cost and a lost-option value that must be included in the cost of investment.

In addition, the competitive equilibrium of a market is virtually never stationary, even in the long run. Rather, it is a dynamic process in which prices can fluctuate widely, and, thus, contribute to uncertainty. Neither classical investment theory nor discounting methods such as NPV take these factors into account. Yet, for long-term, capital-intensive investments such as oil exploration and IT infrastructure modernization, price fluctuation constitutes significant risk—which must be factored into investment decisions (1994, p. 396).

These difficulties are due to an underlying limitation common to both classical investment theory and valuation methods such as NPV: their reliance on simple equilibrium relationships between rates of investment and risk, which has the practical effect of precluding the effect of uncertainty and irreversibility on investment. The factors that adversely impact NPV also impact the accuracy of Planned Value benchmarks that are the basis of Earned Value Calculations (Suter, 2006, p. 406). For these reasons, "classical" methods have met with little success in providing accurate valuations of Public investments and qualified success for those in the Private Sector.

Capital Asset Pricing models such as Black-Scholes, however, sidestep these problems by transforming the analysis from a deterministic formulation to one based on probability. To handle uncertainty and risk driven by price fluctuations, it uses the *Ito Lemma* to compute valuations. Black-Scholes proceeds from the assumption that there is a true value for a stock that corresponds to its risk, and that value can be used to decide whether the market price for a stock is too high or too low. That is, an option's value equals the value of the information concerning that risk.

Black-Scholes models the price of a stock option as a Market-driven process defined by Eqn [3.1], the fundamental condition of equilibrium (Dixit & Pindyck, 1994, p. 115; Cover & Thomas, 1991, p. 28):

[3.1] $\mu = r + \theta * \sigma * p_{xm}$

Where:

μ = the risk adjusted return

θ = market price of risk

r = riskless rate of return

p_{xm} = coefficient of correlation between returns on the particular asset ("x" subscript) and the entire market portfolio of stocks (denoted by the "m" subscript).

σ = the proportional variance parameter

dz = the increment of the standard Wiener process

The computational efficiency of Black-Scholes model enables Floor Traders (and computer-programmed trading algorithms) to exploit small, short-term price fluctuations in real time and to use new pricing information to continually rebalance portfolios. Investors (as distinguished from Floor Traders by virtue of their longer-term time horizon) find Black-Scholes no less useful because of its ability to link risk to valuation over timeframes ranging into years. More recent refinements such as Levy processes introduce more realism by generalizing Brownian motion processes to include discrete state jumps. (The jumps can be local, global, simultaneous, independent or correlated.)

The significance of Black-Scholes is its computational efficiency for modeling price, interest, and discount rates—using a few readily observable parameters that provide reasonable approximations to the underlying physical processes using methods based on the Law of Large Numbers. In particular, it specifically eschews unobservable/hard-to-measure parameters such as "investor psychology." The Black-Scholes strategy is at variance with efforts to improve the analysis by increasing the dimensionality of the problem via the addition of more parameters (as is often done with econometric models, and on occasion with Balance Scorecard methods). The addition of extra parameters may well provide a more detailed picture of performance, but at additional cost and without necessarily improving the accuracy needed for decision-making (McShea, 2006, November, p. 31). As a result, these refinements have added relatively minimal value and can be relatively expensive to implement.

The key is to recognize that decision-making is not necessarily dependent on a detailed understanding of causality to be effective. Thus, Capital Asset Pricing models focus on those few variables with the most explanatory power. The objective is not to predict which firms are most likely to succeed, but only what they are "worth" as measured against various combinations of risk, uncertainty, interest rates, and competing investment opportunities. The task of this paper is to provide equivalent, computationally efficient methods for estimating valuations in public-sector investments, using the fewest parameters with the most predictive power.

There are, of course, methods other than market-based Capital Asset Pricing for determining asset valuations. But, these also suffer from various limitations. For example, Dynamic Programming (DP) could be applied to public-sector investments and is useful in solving multi-stage optimization problems, but only if a small number of possible choices exist at each stage. Indeed, a small increase in the number of possible choices leads to a combinatorial explosion, thus curtailing overall efficiency of DP.

Another method is the Discrete Binomial Model, which uses a risk-adjusted stochastic process for modeling the underlying asset. The strategy is to approximate uncorrelated investment dynamics using two basic ideas: a change of time scale and a change of the basis of the asset span to approximate uncorrelated geometric Brownian motion. Yet another variant, the Lattice Binomial model, has proved useful for valuing complex option problems when payoff depends on multiple state variables that follow correlated geometric Brownian processes. In this case, the strategy is to approximate a multi-dimensional geometric Brownian motion with a binomial lattice by choosing the size and the probabilities of the jumps so that the characteristic function of the discrete distribution converges to the characteristic function of the continuous distribution.

But, both methods require knowledge of the underlying probability distributions—a requirement that can be difficult to satisfy—and will converge to a solution only in the limit. For practical applications, the time required to acquire sufficient data to identify a convergent solution can preclude widespread application, especially if the time value of information rapidly declines, thus forcing the decision-maker to decide on acting with incomplete information, or on risking being overtaken by events.

Information Theory and "Synthetic Prices"

In competitive markets, a single number—the price of a Firm's stock—represents risk. Under ideal conditions that price fully captures the Firm's internal efficiencies, Return-on-Investment (ROI) and earning potential. Those efficiencies determine the Firm's capability to harness new information as it becomes available. For private-sector firms, prices provide two important types of information:

1. The rate at which information becomes known.

The rate is analogous to the diffusion problem in heat transfer, which means that information diffusion can be modeled as a Brownian motion processes.

2. How information is aggregated.

In the private sector, the efficiency of aggregation indicates market efficiency; yet, while no such aggregation occurs in public-sector markets because there is no incentive.

Hayek was the first to identify these effects and to provide the rationale for defining markets in terms of their information value. The definition, in highly abbreviated form, is as follows:

> Competitive markets provide for the efficient coordination of decisions involving time and uncertainty. The process can be modeled as a Random Walk (in which the limit is approximated by a Brownian motion process). The rationale derives from the fact that where information flows without impediments, stock prices immediately reflect the latest information—so that a price change today will reflect only today's news and is independent of any prior price change (such processes are a weak form of market efficiency and have been modeled with some success using Markov models) (Dixit & Pindyck, 1994, p. 63). And, since news often is unpredictable, price changes are also unpredictable, but fully reflect all known information—thus, justifying the Random Walk interpretation.

> However, competitive markets are not the only mechanism for determining investment valuations. A Firm's internal (information) processing efficiencies enable it to reallocate resources based on new information—and, thus, to manage risk. The efficiency of that process can be measured independently of market-based valuation. In this way, it can be applied to public-sector Firms to construct "synthetic prices"—thus linking valuations of its investments to its asset of a Firm: the ability to process information efficiently.

> For the private sector, perturbation-based measures should converge in the limit to the market-based valuation, thus providing a basis for testing the validity of using the internal efficiencies to derive a "synthetic price" for the value of a Firm (Hayek, 945, September, p. 35).

> In fact, the latter should reflect more accurately the "true" value of a Firm, which is what "Value Investors" and Hedge Funds are constantly trying to identify. Indeed, perturbation-response models offer a means to quantitatively link micro, Firm-level models to macro, policy-level models.

Pricing Public-sector Investments

Measures of investment efficiency for the public sector enable a portfolio manager to keep investments allocated to the most profitable outcomes—despite shocks and perturbations to operations. But, effective Portfolio Management depends on accurate pricing information. When information is limited or uncertain, risk is not efficiently priced. As a result, the marginal social utility of an investment will not equate to its price—thus, leaving no means to identify a "socially optimal" level of investment in either the private or the public sector. The net effect is analogous to Nash Equilibrium: a sup-optimal investment equilibrium condition that occurs when no player has incentive to unilaterally change strategy—because a change by any one of them would lead that player to earn less than would be obtained by remaining with the current strategy (Cover & Thomas, 1991, p. 460, 475; Dixit & Pindyck, 1994, p. 147, 283).

Sub-optimality can be driven by limited information, by a lack of incentives to change (as is the case for the Nash Equilibrium), as well as by uncertainty driven by factors such as market volatility. Higher volatility estimates reflect greater-than-expected fluctuations in underlying price levels and result in higher-option premiums for both puts and calls. With respect to the internal processing efficiencies of a Firm, the Taguchi's common and special

sources of variability drive the perturbations of a Firm's workflow (León, Shoemaker, & Kacker, 1987). The efficiency of response determines whether and to what extent a Firm can synthesize information into actionable decisions in a timely manner. The often inconclusive, interwoven, and ambiguous nature of available information can result in time consumed to assess its value, which depreciates the time value of information. The resulting delay propagates uncertainty, which equates to opportunities lost. How much time is required to resolve the ambiguity is a function of a Firm's ability to manage that variability, which depends on its ability to synthesize information.

The impact of information efficiency can be measured in terms of response to random perturbations. The parameters characterizing the perturbations include the amplitude and time lag for changes in valuation and resource allocations, the amount of work/rework completed, requirements churn, the ratio of assets invested to return on those assets, output price/cost, fluctuations in labor, resource availability, the time to close major issues, the time to identify and to minimize both special and common causes of variability, schedule, and price, etc. Note that while these parameters indicate a Firm's internal information processing efficiencies with respect to work progress, much as Earned Value does, they say nothing of business value—i.e., whether the product provides anything useful to a customer.

The perturbation-responses are governed by structure of a Firm, which can be represented as a quasi-deterministic State Variable model. The combination of these techniques also can be used to identify the boundaries beyond which the magnitude of the perturbations would result in unstable responses and project failure (Ford & Taylor, 2006, pp. 337-369).[30] Information Theory benefits the analysis through the provision of algorithms that reduce the number of (perturbation-response) states to be considered in evaluating a process. The larger the number of states, the greater the lack of specificity or uncertainty (entropy) of the system. The following, highly over-simplified example illustrates the point.

The number of states that a single dice can assume is 6. But, if we know that the dice is in some sense biased toward either even or odd numbers (i.e., we have additional or "side" information), then the number of states that need to be considered is effectively reduced to 3, thus changing the outcome probabilities but not the probability distribution model. Alternatively stated, the entropy (disorganization) of a system does not depend on the actual values taken by the random variables describing it, but only on the associated probabilities.

Changes in the probability space, driven by changes to the efficiency of information flows within a Firm, provide a quantitative basis for linking the efficiency of information/knowledge management to well-defined mathematical processes, thus providing quantitative measures of risk that correspond to the underlying physical processes.

Information Theory can enable decision-makers to reduce risk, often drastically, by providing a quantitative framework to address issues such as:

1. The quantitative determination of changes in the uncertainty levels associated with cost/schedule/resource estimates as a project proceeds through its lifecycle.

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[30] Ford and Taylor's text provides detailed discussion of project/program stability.

2. Discounting the anticipated benefits from a project—by measuring risk as a function of the time lags and amplitude of a Firm's response to various types of perturbations.

3. Identifying and reducing (both normal and special) sources of variability that adversely impact work progress and service/product quality

4. Constructing rules to achieve optimal investments—in terms of ensuring that a Firm's decision-making/information is efficient

5. The use-state variable models to estimate whether, and at what rate, investment management is improving

Models capable of answering these questions we consider next.

Computational Models

The Firm's responses to the perturbations provide the raw data from which (indirect) measures of that efficiency can be expressed in terms of factors such as the time lag and amplitude of responses, and the variability of both. The perturbation/response processes are modeled using state variable regulator/ controller design methods. One of the best known and widely applied is the Kalman Filter, which can be used to measure how uncertainty propagates over time, and, thus, calculate the information-carrying capacity of a Firm.

The output of the Kalman Filter model is the amount and rate of *information gain* produced by various organizational structures. The magnitude and rate of correction serve as measures of a Firm's information processing capability, and (by implication) its level of entropy or level of internal-information organizational efficiency. The more efficient the Firm, the more quickly it will respond to perturbations (random shocks) regardless of source, internal or external. (The situation is analogous to determining the bandwidth of a communications system).

Schematically, the Kalman Filter information flow/computation cycle is illustrated in Figure 1, below.
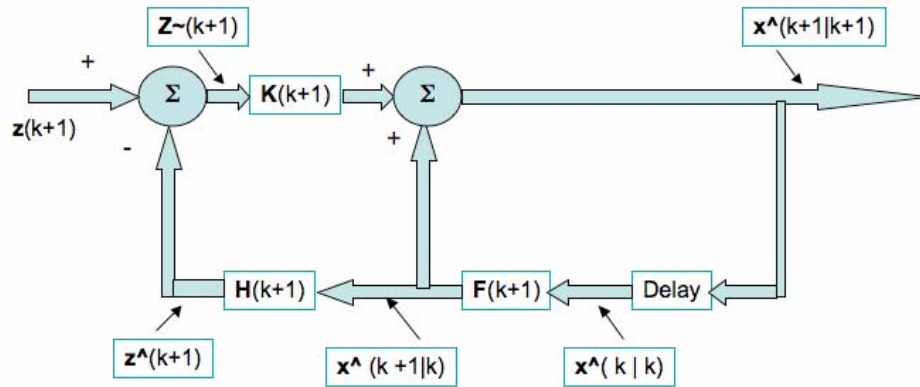
Kalman Filter

Figure 1. Kalman Filter

Kalman Filter Computation Steps

Legend:

x is the vector of variables comprising the system, whose state is to be estimated over the successive time (e.g., multi-stage investment) periods k =0,1,2,…

$x \wedge (k+1|k)$ is the predicted estimate of x for time "k+1" based on measures taken at time "k."

z is the actual, uncorrected measurement of x.

z ~ is estimate of x when corrected errors are introduced by the measurement process.

z ^ is the estimate of x ^ as filtered by H.

H is the measurement transformation matrix that relates the system state vector, x, to its measure, z.

Delay is the lag in system response to a stimulus. Delay is inherent to an organization because information cannot be gathered, analyzed, or transmitted instantaneously. Thus, changes in the environment or slips in schedule may or may not be recognized when they occur. For example, decreases in data quality typically generate increased disruption in operation. As more resources are shifted to fixing and correcting data records, the rate at which information is processed decreases. The resulting inefficiency generates increased correction and rework rates, along with increase delays in task completion.

F is the coefficient matrix of the state variable vector x. It describes the input/output efficiencies of a Firm and its investments. If these change overtime, then F (k) =/= F (k+1), k=0, 1, 2… and the system described by Eqn (1), (2), below, would be non-linear in time "t."

The steps presented in Figure 1 are as follows:

1. Begin with $x^\wedge(0 \mid 0) = 0$, for k = 0, 1, 2… Use $x^\wedge(k \mid k)$ to iteratively compute $x^\wedge(k+1, k+1)$ given z(k+1).

   Where:

   x^ (k | k) Is the estimate propagated forward by pre-multiplying it by **F**(k+1, k) to give the predicted estimate **x^**(k+1 |k).

2. Pre-multiply $x^\wedge(k+1 \mid k)$ by H (m +1) to compute is $z^\wedge(k+1 \mid k)$, which is then subtracted from the actual measurement z (k+1).

   - The result is **z~**(k+1 | k), which is the measurement residual—that is, the difference between actual and predicted estimates at time (k+1).

3. The residual, z ~, is pre-multiplied by K (k+1), the Kalman Filter coefficient matrix, which is added to $x^\wedge(k+1 \mid k)$.

   - The result is $x^\wedge(k+1 \mid k+1)$, which is the estimate of x at time (k+1), given the measures updated at time (k+1).

4. $x^\wedge(k+1 \mid k+1)$, the optimal filtered estimate, is stored until the next measurement is made—at which time the cycle is repeated. (This is the only data that needs to be stored between measures, thus saving considerable computer storage and memory.)

Note that the product **K** (k+1)***z~**(k+1 | k) is the correction that is added to the predicted estimate **x^**(k+1 |k) to determine the filtered estimate.

The optimal filter consists of the model of the dynamic process which performs the function of a prediction and feedback correction scheme in which the gain-times-residual, **K** (k+1) ***z~**(k+1 |k], per Eqn [3] below enters the model as the forcing function **u**(k) (Meditch, 1969, p. 182).

How all this works is illustrated by the following state-variable model for which the following assumptions are made.

- Time delay decreases the volume of work accomplished per unit of time.

- Time delay is driven by unstable/poorly managed requirements, funding instability, etc., thus acting to increase the amount of rework.

- In this example, model parameters are assumed to be Gaussian (Normally) Distributed, with side information (e.g., feedback) entering into the system as a sequence of predict-correct actions.

x(t) is the vector of state variables, which consists of the two elements:

x_1 (t) =Volume of work/unit of time,

x_2 (t) = Volume of rework/unit of time.

The state variable model is:

[1] **x'** = **F* x** (t) + **u**(t)

(where **x'** = d**x** (t)/dt) = [x_1', x_2'] = [dx_1 (t)/dt, x_2' = dx_2 (t)/dt]

[2] [x_1'] = [1 1] [x_1(t)]   + [1   0] [u_1 (t)]

        [x_2']   [0 1] [x_2(t)]   [0   1] [u_2 (t)]

Verbally, Eqn [2] states that the rate of change in work package completion is the sum of the current workload (x1) + rework (x2) + the arrival of new work (u1). The rework rate (x2') is equal to the sum of current rework (x2) + new rework (u2), where the vector u(t) is governed by the corrections provided by Eqn [3].

The control vector **u**(t) = [u_1(t), u_2(t)] is defined in terms of predictor/corrector parameters as:

[3] **u**(t) = **K**(t)*[**z** − **H* x^**]

Eqn [3] computes the correction, given **x^** from the Kalman Filter Eqn [9], below.

[4] **e**(t) = **K** (t)*[**v** − **H** *(**x** − **x** P)]

Eqn [4] computes the error estimate *prior to* measurement.

Eqns [3], [4] derive from the linear measurement Model:

[5] **z** = **H* x** + **B** * **v**

To keep the computation simple, **H**, **B** are defined as identity matrices:

H = [1   0]

        [0   1]

B = [1   0]

        [0   1]

v is a vector of random measurement errors which are independent of the state **x. (v** is implemented with Monte Carlo simulation input.)

Eqn [1] and Eqn [2] can be cast into Kalman Filter format by defining the following parameters:

X P is the Estimate of the system state *prior to* measurement, as defined in [7-P], below.

P_P is Covariance of the system state *prior to* measurement, as defined in [7-P], below.

x_A is the Estimate of the system state *after* measurement, as defined in [7-A].

P_A is Covariance of the system state *after* measurement, as defined in [7-A].

[6] $R = E[v*v']$ Is the mean of the measurement error vector.

[7-P] $P_P = E[(x_P - x)*(x_P - x)^T]$ Is the error covariance matrix *prior* to measurement.

[7-A] $P_A = E[(x_A - x)*(x_A - x)^T]$ Is the error covariance matrix *after* measurement.

[8] $x_A = x_P + P_P *H_P{}^{T}*R_P{}^{-1}(z - H* x_P)$ is the optimal estimate.

Eqn [8] is a model of Eqn [1] with a correction term that is proportional to the difference between the actual measurement z_i and the predicted measurement H_i*x_i

To minimize the subscript clutter used to denote the *before* and *after* calculations, P_A is changed to **P, for after,** and P_p to **M, for prior.** Thus, indexing Eqn [8] for measures over successive discrete time periods becomes Eqn [8'].

[8'] $x^\wedge_i = x^-_i + K_i (z_i - H * x_i^-)$, where i =m, m+1 ….

for multi-stage investments.

The Gain Matrix for the Kalman Filter, for time periods i = 1, 2… is

[9] $K_i = P_i * H_i{}^T *R_i{}^{-1}$

Eqn [9] can be interpreted as the proportionality matrix or the ratio between uncertainty in the covariance matrix P_i, after measurement at time "i" and uncertainty in the measurements R_i Eqn [6] (which can be interpreted as the effectiveness of a management reporting system).

The propagation of uncertainty in the *discrete* time system, Eqn [11], below, is based on the computation of:

[10] $P_i = (M_i{}^{-1} + H_i{}^T*R_i{}^{-1}*H_i)^{-1}$

[10'] $P_i = M_i - M_i * H_i{}^T *(H_i * M_i * H_i{}^T + R_i)^{-1} H_i * M_i$

[11] $M_{i+1} = F_i *P_i *F_i{}^T + G_i *Q_i *G_i{}^T$

Eqn [11] reflects the balance between the new information-forcing function,

$\mathbf{G}_i *\mathbf{Q}_i *\mathbf{G}_i^T$; and, information processing efficiency, $\mathbf{F}_i *\mathbf{P}_i *\mathbf{F}_i^T$. (In a traditional physical system, $\mathbf{F}_i$ would represent the damping efficiency of the system. Collectively, Eqn [10], [10'], and [11] describe the propagation of the covariance of the error estimate, which are independent of the measurements $\mathbf{z}_i$.

Eqn [9]-[11] Is the Kalman Filter for a multi-stage process.

Prediction beyond the last measurement for states indexed as i = m +1, m+2, … is given by Eqn [12].

[12] $x_{(i+1)} = F_{(i)} * x_{(i)} + G_{(i)} *U_{(i)}$

Figure 2, below, provides a heuristic illustration (via the use of "canned" data) of the damping out effects of the Kalman Filter (illustrated by the magenta colored line), the retardation of that effect induced by response delay (as denoted by the green dashed line), with the black line illustrating the impact of a special cause of variability, such as the failure of an integration test, a reduction in funding, a major equipment failure, etc. The blue dashed line (highly exaggerated) illustrates "normal" variability causes, which might include ambiguous governance, the impact on products and services due to aging equipment, but which shows gradual improvement overtime.
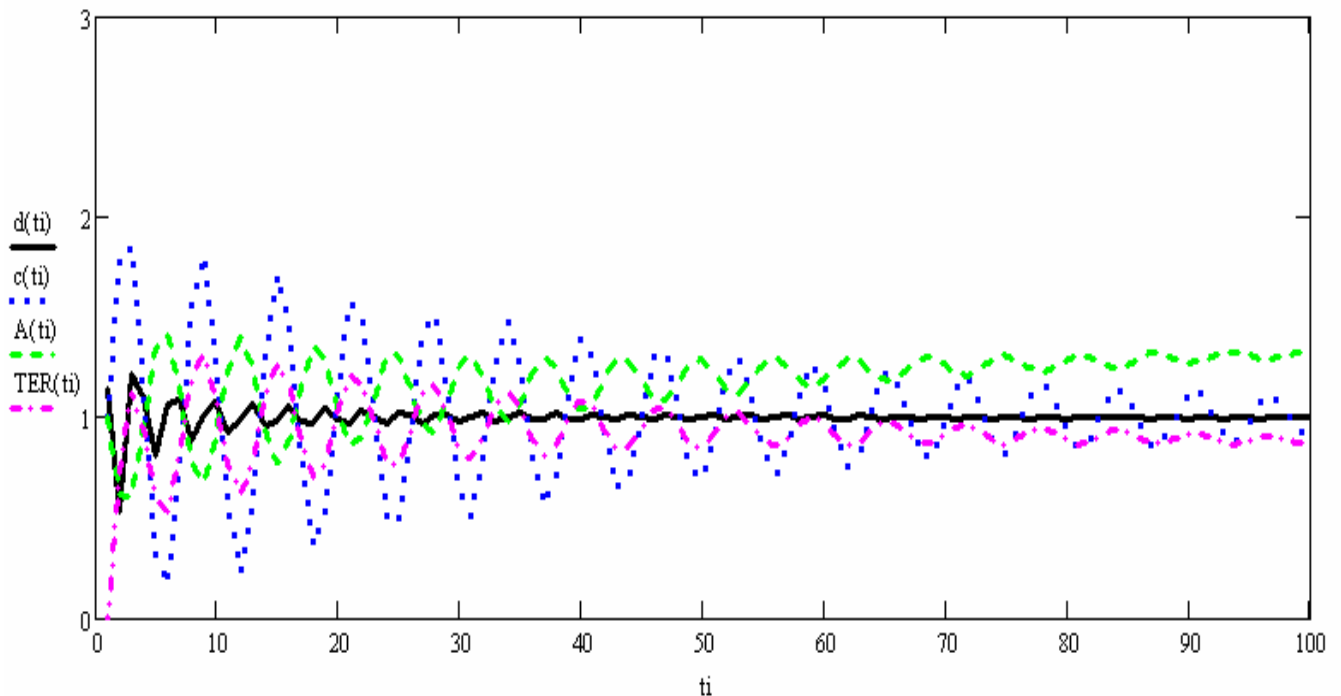

Figure 2. Perturbation-response Output from Kalman Filter

Summary/Next Research Steps

The strategy and models outlined in this brief paper indicate how Information Theory can be used to quantify the value of information and translate that value into a "price" for public-sector investments that, in principle, is comparable in a competitive market.

The next steps include:

- Fully defining the conditions under which the synthetic prices for public-sector goods are comparable in competitive markets.
- Developing methods to normalize comparisons across portfolios of diverse investment projects.
- Applying and evaluating the models using "real" data from public- and private-sector IT infrastructure investment projects.
- Using the model output to evaluate "synthetic prices" based on information gains defined using Kalman Filters.
- Comparing model results across a range of scenarios.
- Identifying algorithm improvements that accelerate convergence to specific price solutions.

Glossary

Term	Description
Black-Scholes model	A mathematical model used to calculate the value of a project or an investment as derived from market-place dynamics, based on approximations to Brownian motion processes
Brownian Motion	The random motion of particles in a liquid. The mathematical model of describing this motion is the Wiener process. A continuous time process that forms the basis of many important mathematical models in thermodynamics and Finance
Binomial Lattice Methods	An algorithm for valuing complex option problems whose payoff depends on multiple state variables following correlated geometric Brownian processes
Capital Asset Pricing (CAP)	The concept that there is a true value for a stock corresponding to its risk, for which various computational models can be used to determine risk-adjusted discount rates for investments, and to decide whether a stock price is too high or too low.
Complexity	There are at least two basic types of complexity: Descriptive complexity of an object—Kolmogorov complexity. While not directly computable, it can be bound between computable measures to describe the complexity of a sequence of symbols; Computational complexity—measures the time or space required for a computation
Derivative	A financial instrument that derives its value from the value of some other financial instrument or variable. For example, a stock option is a derivative because it derives its value from the value of a stock. An interest-rate swap is a derivative

	because it derives its value from one or more interest rate indices
Dynamic Hedging	The purchasing/selling of financial instruments to reduce or cancel out the risk in another investment as required by changing market conditions
Earned Value	Measures the dollar-value work completed per unit of time. It is a measure of progress against an objective, from which schedule (SC) and cost variances (CV) can be computed using Planned Value (PV) and Actual Cost (AC). SV = EV − PV CV = EV − AC. But, realistic estimates of Planned Value are seldom available—especially at the on-set of a large, complex project. Hence, the value of Information Theory lies in determining when and to what extent confidence can be placed in a benchmark such as Planned Value
Efficient Frontier	A concept that there is a true value for a stock corresponding to its risk; this theory of stock price is called Capital Assets Pricing Model and is used to decide whether a stock price is too high or too low.
Entropy	A measure of the disorganization of a physical system/The uncertainty of a single random variable/The minimum descriptive complexity of a random variable. An irreducible level of complexity below which a signal cannot be compressed
Equity Markets	A (competitive) stock market that efficiently coordinates decisions involving time and uncertainty
Exogenous	Refers to variables whose values are driven by factors external to the firm, or processes, of interest
Firm	In this paper, the "Firm" refers to an organization in either the private or public sector tasked with investing in and developing new products and services
Game Theory	The branch of applied mathematics and economics that studies situations where players choose different actions in an attempt to maximize their returns. It provides a formal, quantitative modeling approach to social situations in which decision-makers interact
Information Theory	A discipline spanning mathematics, economics, physics, communication theory, statistics, involving the quantification of data. For communications, the goal is to enable as much data as possible to be reliably stored or communicated over a channel.
Ito's Lemma	Is used to integrate and differentiate stochastic processes. An *Ito process* can represent the dynamics of the value of a project which does not have a time derivative in the conventional sense- because its fluctuations over (short) periods of time do not have derivatives
Kalman Filter	A mathematical algorithm that operates in a predict-correct fashion that uses feedback to maintain a system (e.g., a rocket, or an investment portfolio) on a desired trajectory
Levy Process	A generalization of Brownian Motion processes to include discrete state jumps. The jumps can be local, global,

	simultaneous, independent or correlated
Law of Large Numbers	The sum of independent, identically distributed random variables that can be approximated arbitrarily closely to the expected value of the random variables
Markov Property	The property of a process that current information is useful for forecasting the future path of a process. Applied to Stock processes on the premise that public information is quickly incorporated into the current price /D-63/
Mutual information	The communication rate (efficiency) in the presence of noise. It is a measure of the amount of information that one random variable contains about another random variable. It is the reduction in the uncertainty of one random variable induced by knowledge of the other
Nash Equilibrium	A condition in Game Theory in which no player has incentive to unilaterally change her action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy
Net Present Value (NPV)	NPV is a standard method for the financial evaluation of a long-term project. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows (in present value (PV) terms) once financing charges are met. By definition, NPV = Present value of net cash flows
Options Pricing	Is a contract between a buyer and a seller, or a provision of a contract, that gives one party (the option holder) the right, but not the obligation, to perform a specified transaction with another party (the option issuer or option writer) according to specified terms. Option contracts are a form of derivative instrument
Portfolio Management	The discipline of managing a portfolio of investments with the objective of maximizing the value of the entire portfolio by reallocating resources among the investments comprising the portfolio
Public-sector Firms	Firms such as public health or security tasked with providing goods and services whose valuations are not saleable in private equity (i.e., stock) markets, but which benefit society
Random Walk	A process that takes a discrete move in a specific direction according to a specified probability distribution. The Brownian Motion (Weiner process) is the limit for the discrete random walk process
Rate Distortion Theory	A major branch of information theory; it addresses the problem of determining the minimal amount of entropy (or information) that can be communicated over a channel, so that the source (input signal) can be approximately reconstructed at the receiver (output signal) without exceeding a given distortion level.
Risk	"Risk" is randomness with knowable probabilities; "uncertainty" is randomness with unknowable probabilities. Frank Knight (1921): An engineering definition of risk is "the (probability of an adverse event) x (loss per event)"
ROI—Return on Investment	A measure of the net income a firm is able to earn with its total assets. Return on investment is calculated by dividing net

	profits after taxes by total assets. The Rate of Return (ROR) or Return on Investment (ROI), or sometimes just return, is the ratio of money gained or lost on an investment relative to the amount of money invested. The amount of money gained or lost may be referred to as interest, profit/loss, gain/loss, or net income/loss. The money invested may be referred to as the asset, capital, principal, or the cost basis of the investment.
Side information	Information that is relevant to the outcome of an event such as a coin toss, or a horse race
System Control Theory	The discipline of controlling complex machines such as aircraft, computer networks, financial and manufacturing systems
Uncertainty	A characteristic of a random variable that is measured as Entropy. It is the number of bits required to describe a Random Variable. The larger the number of values that the random variable can take, the larger the uncertainty.
Variability: Special and common sources	A common source of variability: The quality level of an item created by a machine tool that is wearing out. A special source: an unlikely event such as the breaking of an artifact being processed by machine tool that fails unexpectedly

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Dynamic Cost-contingency Management: A Method for Reducing Project Costs While Increasing the Probability of Success

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Abstract

In the real world, "Money Allocated is Money Spent" (MAIMS). As a consequence, cost underruns are rarely available to protect against cost overruns, while task overruns are passed on to the total project cost. The combination of the probabilistic aspects of project costs and the MAIMS principle have important implications for budget allocation and the management of contingencies. Project costs depend not only on the desired probability of success but also on budget allocation and contingency management. This is in contrast with both deterministic practices that allocate a percentage of the project baseline cost for contingency as well as today's de-facto probabilistic cost analyses that provide a cost contingency independent of the budget-allocation strategy. The realistic modeling of cost uncertainties and the MAIMS principle provide a framework for developing a viable cost-management strategy for allocating baseline budgets and contingencies. Based on this analysis, the project manager can maintain a realistic project-wide contingency and dynamically distribute it to the individual risks on an as-needed basis. Projects that implement dynamic cost-contingency management based on these principles are likely to achieve a higher probability of success and cost less.

Introduction

Real-world experience and intuition both suggest that project costs depend on many factors, including technical, organizational, and behavioral considerations. Thucydides got to the very root of the cost-overrun problem over 2000 years ago when he stated, "Their judgment was based more on wishful thinking than on sound calculation of probabilities" (Augustine, 1997, p. 255).

In the 1990's, the Lockheed Missiles and Space Co. carried out a study which concluded that the following deficiencies in cost modeling and contingency management have been major contributors to both project high costs and overruns (Gordon, 1997):

- Hidden incentives in procurement

- Hidden incentives in management styles

- Failure to coordinate cost analysis and cost management

- Use of invalid mathematics such as arithmetically summing uncertain cost elements instead of using statistical methods

- Overlooking the "Money Allocated Is Money Spent" (MAIMS) principle

The MAIMS principle accounts for the fact that projects rarely underrun their allocated budgets. It is the money analog of Parkinson's Law, "Work expands to fill the time allotted." The principle is also in concordance with Goldratt's observation that negative human behavior is a major cause of the project-scheduling problem. Goldratt (1997) developed the Critical Chain Project Management (CCPM) as a management philosophy and solution that simultaneously reduces project duration and protects against schedule risk. A key principle of CCPM is to aggregate task buffers at the project-level for use where and when needed. But it also proposed the following guidelines for sizing buffers: (1) cut task duration estimates in half, and (2) add approximately 25% of the original estimate to the project buffer. These guidelines appear to be rather arbitrary, and many technical managers are uncomfortable with them. A number of simple alternatives to estimate and sum buffers have been proposed (Newbold, 1998; Schuyler, 2001). We think that their use is no longer justified because of the availability of simple Monte Carlo simulation tools such as @Risk® and Crystal Ball®.

The premise of this paper is that a credible Probabilistic Cost Analysis (PCA) needs to integrate findings on human behavior with mathematically valid models and sound management techniques to obtain realistic cost estimates and achieve project success. A key recommendation is that in order to deliver successful projects at an optimal cost project, management needs to allocate "reasonable" budgets to the cost-account managers and dynamically manage the cost-contingency funds as a risk portfolio at the program/project level.

Proposed Modifications to Today's Typical PCA

Assessing Uncertain Cost Elements

R&D and complex engineering projects rely heavily on engineering/expert judgment for the assessment of uncertain cost elements. Unfortunately, these subjective assessments are often performed in a rather ad-hoc manner, and they have been identified as a critical source of error in probabilistic risk analyses (Keeney & von Winterfeld, 1991). The Direct Fractile Assessment (DFA) method has been investigated in numerous psychological experiments and found to provide one of the most reliable and least bias-prone procedures for eliciting uncertain quantities (Alpert & Raiffa, 1982). We recommend that experienced analysts and domain experts determine the 10th, 50th, and 90th percentiles for uncertain cost elements. While other percentiles may be used, these seem to be highly practical (Dillon, John, & von Winterfeld, 2002).

Fitting Cost Elements with Realistic Probability Density Functions (PDF)

Uncertain cost elements are more appropriately modeled as continuous than discrete random variables. We favor the use of the three-parameter Weibull distribution because it is an

open-ended function that can assume a wide variety of shapes (Kujawski, Alvaro, & Edwards, 2004). It is also more flexible than the three-parameter lognormal even though both are characterized by three independent parameters. The use of more complex PDFs seemed unwarranted for fitting three subjectively assessed percentiles. Analysts and assessors should always validate that they feel comfortable with the shape of the fitted distribution.

Incorporating the MAIMS Principle

The MAIMS principle plays a significant role in PCA. Once a cost element is allocated a budget, x* it becomes a random variable with minimum value x* rather than the lower range of the original PDF. The cost element is then given by a PDF with a delta-like function[31] (or spike) at x* that accounts for all random values less than or equal to x* and the original distribution for values greater than x*. The associated Complementary Distribution Function (CDF) has a step-function behavior at x* and is identical to the original CDF above x*. The effect on the cost element is that its mean increases and its standard deviation decreases with increasing values of x*. As a result, the MAIMS principle plays a significant role in budget management.

Modeling Specific Risks

The above PDFs provide a macroscopic rather than a microscopic view of the project cost risk. They effectively model those factors or project characteristics that are ever present and contribute to cost uncertainties. But complex projects often involve a number of critical decisions and high-impact risks which call for explicit risk-mitigation actions. A detailed PCA should incorporate both the macroscopic and microscopic views to ensure that all risks and cost uncertainties are addressed and that the risk-reduction activities are transparent (Chapman & Ward, 1997). The analysis of specific risks and risk-response actions requires a microscopic view and is best carried out using tools such as decision trees, influence diagrams, or other discrete representations (Kujawski, 2002a).

Modeling Correlations

Cost elements are correlated because project characteristics (such as complexity, criticality, management, staff, and processes) are likely to impact multiple cost elements at the subsystem and system levels. Also, the realization of any one risk is likely to influence other risks and to increase their probabilities and/or consequences. Kujawski, Alvaro, and Edwards (2004) have developed a Two-Level Correlation Model (TLCM) which greatly reduces the number of parameters needed to specify a mathematically valid and physically realistic correlation matrix. In its simplest form, it models correlations among cost elements of the same and different subsystems with only two parameters, ρ_{int} and ρ_{ext}.

Application to a Representative Design and Engineering Project

To investigate the concepts and issues discussed in the previous sections, we consider a hypothetical project with three level-2 cost elements (project/system-level and two

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[31] Caution: The MAIMS-modified PDFs are not the same as the Crystal Ball® and @Risk® truncated PDFs.

subsystems) each with three level-3 cost elements. Figure 1 depicts different budget-allocation strategies for a given set of PDFs and TLCM parameters[32].
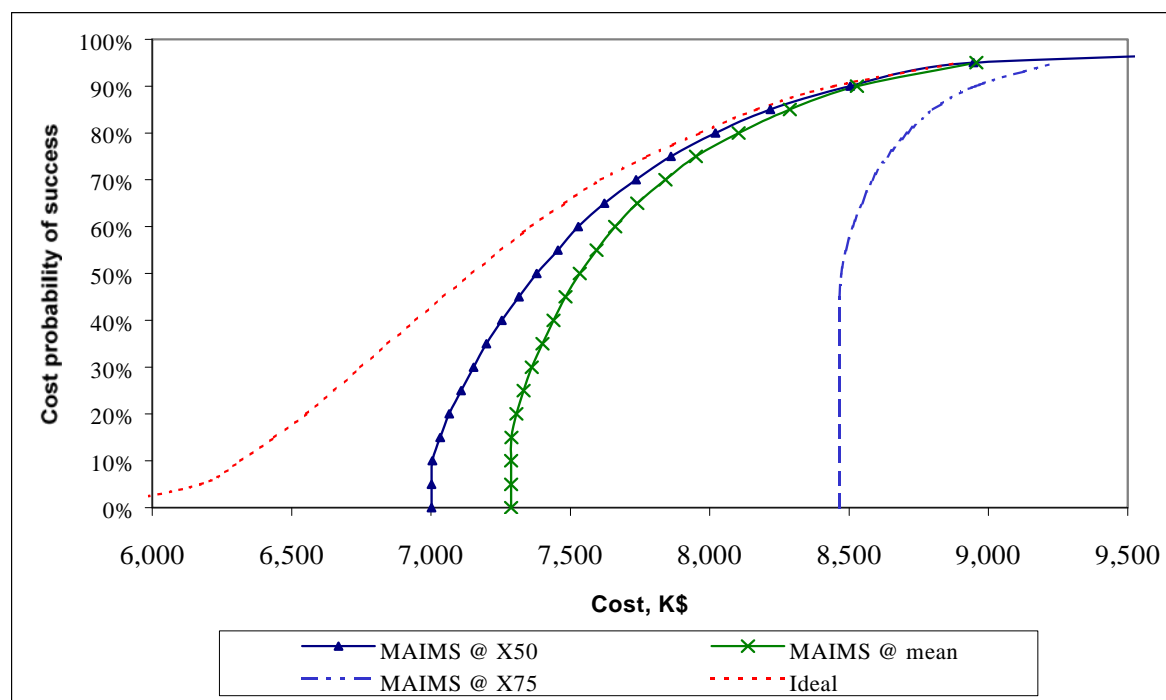
Figure 1. Illustrative Impact of Different Budget Allocation Strategies on Project Cost

Note: The cost elements are modeled with Weibull distributions fitted to the 10th, 50th, and 90th fractiles. The cost correlations are modeled using the two-level correlation model with parameters of 0.6 and 0.4.

The "ideal curve" corresponds to the model where the project staff rationally spends money only as necessary to satisfy the project requirements. In this ideal world, the actual costs may be less than the budgeted costs, and the savings are available to support other project elements on an as-needed basis. In the MAIMS_@_X50 and MAIMS_@_X75 curves, all cost elements are allocated equal percentiles of 50% and 75%, respectively. The MAIMS_@_mean curve corresponds to the case in which each cost element is allocated its mean or expected value. Each cost element is then budgeted at a percentile that depends on the shape of the assessed PDF. The MAIMS effects increase with higher allocated budgets and are substantial over a wide range of Probability of Success (PoS) values of interest to PCA.

Budget Allocation, Contingency, and Project Cost

Our objective is to integrate the presented concepts into a sound methodology for determining an optimal as well as realistic Total Estimated Cost (TEC) and budget-allocation/management strategy for a given PoS. The combination of cost uncertainties and the MAIMS principle complicates the situation. As we have shown, the TEC depends not only on

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[32] The calculations were performed using Crystal Ball® and 10,000 trials.

the desired PoS but also the budget allocation and the management of contingencies. The project cost cannot be estimated until the cost management strategy—including budget allocation—is specified. We like to think that this contains a flavor of the Heisenberg Uncertainty Principle.

Much has been written on cost contingency; but there is still much confusion (Baccarini, 1999; INCOSE, 2003). To shed additional light on the subject, we express the Management Cost Contingency (MCC) in a form that exhibits its dependence on the PoS and the cost management strategy:

$$MCC(PoS, PBC_1,…, PBC_n) \equiv TEC(PoS, PBC_1,…, PBC_n) – PBC.$$

PBC_i is the baseline budget for cost element C_i, and PBC is the probabilistic sum of all the project cost elements. The above relationship contrasts with both (1) the deterministic practice that allocates a percentage of the PBC as MCC, and (2) today's typical PCA that provides a MCC that is independent of the budget-allocation strategy. Figure 2 depicts the TECs and MCCs corresponding to Figure 1.
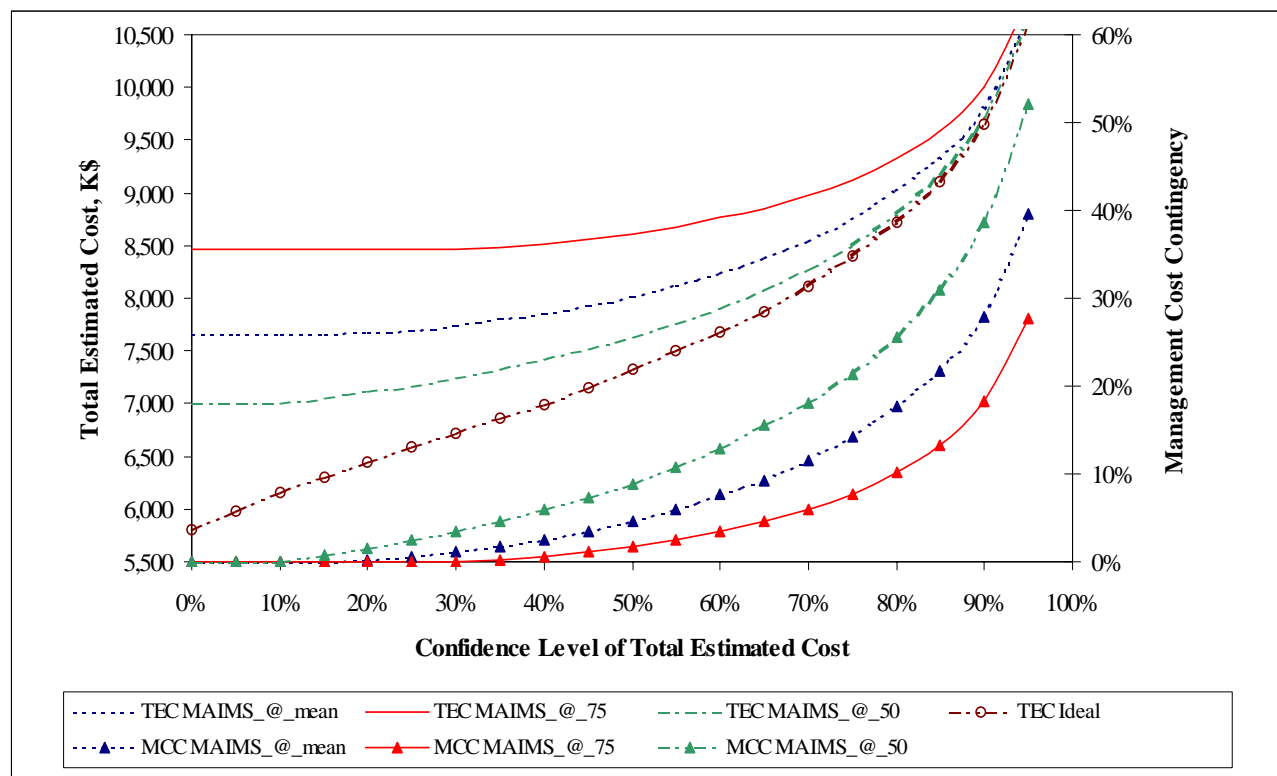
Figure 2. Impact of Different Cost Management Strategies on the Cost and Contingency for the Project in Figure 1

Figure 2 contains valuable information for both the procuring activity and the contractor. The budget management strategy has a significant impact on the TEC for a given PoS. The effects of the MAIMS principle increase with increasing budget allocations and are substantial for all but the very highest PoS values. The MAIMS principle has little impact at the very high confidence levels (CL > 95%) because each contributing cost element must then be near its maximum or 100th percentile value. These results have important implications for cost

management. For example, sizeable cost reductions are achieved by allocating budgets to the cost elements at the 50% CL rather than the 75% CL. The standard PCA that assumes an "ideal" project provides a false sense of confidence; it may be a major source of cost overruns even for projects with high contingencies.

Why Projects Even with High Cost-Contingencies Often Fail

Consider a hypothetical request for proposal for the project[33] depicted in Table 1. To level the playing field, the procuring activity specifies that all bids should provide the 50% CL cost. Contractor A has a certain level of sophistication. He[34] prepares a typical PCA with every bid; but he is not cognizant of the MAIMS principle. He performs today's typical PCA and obtains the CDF in Fig. 2 labeled "TEC Ideal" and a P50 TEC of 7,348 K$. Based on this analysis, Contractor A submits a bid of 7,348 K$ and rationalizes that the proposal is conservative given that the P50 value is 30% above the low estimate of 5,633 K$. But because of the MAIMS principle, Contractor A's risks are significantly greater than he thinks. Once the contract is awarded, management proceeds to baseline and allocate budgets to the cost elements at their mean values. Given that the cost elements are budgeted at their mean values, the TEC is really given by the CDF in Fig. 2 labeled "PEC MAIMS_@_mean," the P50 TEC is 8,071 K$, and the PBC of 7,665 K$ is the lowest achievable cost. To management's surprise, this value is 317 K$ less than the proposal bid of 7,348 K$. Because of the MAIMS principle, there is a negligible likelihood that Contractor A, given his practices, can deliver the project for the submitted bid of 7,348 K$. Table 1 summarizes this and several other scenarios.

Management	Strategy	MAIMS-Modified PCA				Typical PCA			
Budget Allocation	Desired PoS	TEC $K	MCC $K	MCC %	Real PoS	TEC $K	MCC $K	MCC %	Real PoS
Mean	20%	7,673	0	0%	20%	6,445	-1,220	-16%	0%
	50%	8,071	406	5%	50%	7,348	-317	-4%	0%
	80%	8,987	1,322	17%	80%	8,626	961	13%	73%
50% CL	20%	7,111	0	0%	20%	6,445	-557	-8%	0%
	50%	7,692	690	10%	50%	7,348	346	5%	37%
	80%	8,771	1,769	25%	80%	8,626	1,624	23%	77%
75% CL	20%	8,466	0	0%	20%	6,445	-2,021	-24%	0%
	50%	8,613	147	2%	50%	7,348	-1,118	-13%	0%
	80%	9,330	864	10%	80%	8,626	160	2%	52%

Table 1. Some Summary Data for the Different Cost Management Strategies Depicted in Figure 2

Similarly, when considering specific technical risks, the common-sense and mathematically valid solution for efficient-cost risk management is to maintain a project-wide contingency and to distribute it to the individual risks on an as-needed basis. This approach to

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[33] This is the same illustrative project used for Figures 1 and 2.

[34] Gender neutral

managing project technical risks may be thought of as a variant of modern portfolio theory (Markowitz, 1991). The implication to managing project is that less attention should be given to the individual risks (substituted for stocks) and more to the project (substituted for portfolio) as a whole (Kujawski, 2002b). CCPM formalizes analogous concepts and their implementation for project schedule planning and management.

Concluding Remarks

This paper develops a practical and sound framework for quantifying the influence of human behavior on project cost and efficiently managing project risks and cost contingencies. The key elements include:

- The incorporation of the "Money Allocated Is Money Spent" (MAIMS) principle. The probability distribution of each cost element is modified by setting all cost values less than the allocated budget to the allocated budget in the MCS.

- The realistic assessment of cost uncertainties and technical risks using proven methods such as the Direct Fractile Assessment method, event trees and/or influence diagrams.

- The realistic treatment of correlations among cost elements.

- The probabilistic treatment of the cost elements and explicit representation of technical risks. The analysis is readily performed using commercially available Monte Carlo simulation Excel add-ins.

- The implementation of a project-wide cost contingency to ensure the contractually agreed-to or acceptable probability of success.

- Contingencies held and managed at the project-wide level. They should not be allocated at the task-level and held by individual subsystem managers.

- A dynamic allocation algorithm with system-level oversight for managing project risks. However, individual technical risks are still managed by the responsible technical performers. A database for tracking risks would provide a powerful tool for accurately watching and forecasting contingency allocations and for controlling adverse behaviors.

All seven principles are necessary to ensure that adequate contingencies are available to mitigate all project risks and not just selected ones. Projects that implement all seven principles are more likely to succeed and cost less.

The author acknowledges that it takes effort to develop these more realistic models and that all models are only approximations to reality. The single greatest challenge to the development and use of improved probabilistic cost analysis and dynamic budget allocation is the implementation of systems thinking at the personnel, organizational, and institutional levels. But given the magnitude of the cost overrun problem, there is no excuse for accepting the status quo; the benefits are likely to be significant.

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An Enterprise Model of Rising Ship Costs: Loss of Learning Due to Time between Ships and Labor Force Instability

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Abstract

Since the end of the Cold War, the perceived need for Navy ships has dropped, and so the shipbuilding budget has dropped. Seemingly coincidental with this budgetary pressure, and perversely aggravating the problem, ship costs began to rise steeply. We will set aside that ships have grown in weight by about three percent per year since World War II and that ever-more weapon systems are being put into them, and confine ourselves to discussions of costs rising for ships beyond the increase in "content." We will also set aside rises due to commodity prices and inflation and that fewer ships, divided among a fixed industrial base, reduce the base for overhead and reduce opportunity for the effects of quantity-driven learning; these effects are well understood, and yet cost growth in ships exceeds that which they explain. This paper will show two additional effects, each of which causes ship direct labor to rise in a way that has never been adequately modeled. The paper will demonstrate, via a statistically significant model, cost growth both from loss of learning due to increased time between ship starts as well as from the lessening of efficiency due to inexperienced labor caused by fluctuating demand.

Introduction

Since the end of the Cold War, the perceived need for Navy ships has dropped; therefore, the shipbuilding budget has dropped, as has most of the Defense Department's budget. The Global War on Terror (GWOT) has further stretched budgets. Seemingly coincidental with this budgetary pressure, and perversely aggravating the problem, ship costs began to rise steeply. This paper will demonstrate that a significant portion of the increase in ship costs is not a coincidence at all but is a direct result of decreased budgets in an unavoidable way. We will set aside that ships have grown in weight by about three percent per year since World War II and that ever-more weapon systems are being put into them, and confine ourselves to discussions of costs rising for ships beyond the increase in "content." Conventional wisdom holds that fewer ships, divided among a fixed industrial base, causes reduced base for overhead and reduced opportunity for the effects of quantity-driven learning; these effects are fairly well understood, and yet cost growth in ships exceeds the cost growth explained by conventional effects. This paper will show that two additional effects are at play, each of which causes individual ship direct labor to rise in a way that existing models and cost estimating tools do not predict. The paper will explain these two effects and conclusively show their impact.

The analysis that follows will demonstrate, via a statistically significant model, two effects: the effect of less demand and the effect of less-steady demand. The former causes stretched-out ship-class acquisitions, increasing time between ship starts; the latter causes workforce instability. The analysis was conducted first on the *Arleigh Burke* (DDG 51) Aegis-guided missile destroyer program and demonstrated to be statistically significant (25 data points). In order to be absolutely certain of the analysis, as is the custom on important studies, it was conducted a second, independent time, on a wholly different ship type, the *Wasp* (LHD 1) class of amphibious assault ships (7 data points). These ships are nearly four times as big as a DDG, have a different mission, and were built in the same era, but on a significantly different schedule. The analysis revealed the same result and was again statistically significant. The import of this second trial cannot be overstated; it results in dramatic increase in the significance of the results, from the customary 95% significance level to a 99.75% level. The resultant model is called the Advanced Learning Model. (The three progressively more comprehensive versions, ALM 1, ALM 2, and ALM 3, are summarized in this paper.)

Graphics would greatly simplify and clarify this summary, but the necessity of removing values and avoiding the compromise of proprietary data are delaying this process. The paper as presented will show these very illuminating graphics. The authors apologize for the lack of graphics herein and hope the reader will attend the briefing!

ALM 1 Analysis: The DDG Class

The analysis begins with an examination of Vessel Labor (VL), recurring direct labor, in manhours (MH), by ship. The problem that presents itself, in ship class after ship class, is that there is a fairly obvious learning curve for the beginning of the ship class, but at some point this curve fails to predict future ships, and VL begins to rise seemingly without cause. If we simply run a learning curve through the initial ships, and then run subsequent curves as the number of ships rises, we will get an answer that seems to show an ever-flattening learning curve. (As we note later, some parties even claim that learning ceases at some point in a ship class; this is a misinterpretation of the perturbing—and, as we will show, perturbed—data.)

This is a learning curve only in a manner of speaking, because, at some point, the "learning curve" does not pass through the data points in any satisfactory way. There is no "learning curve" other than in the sense that any set of points can have a best-fit line run through them. What is going on here?

One of the problems is that traditional learning curve theory requires a steady work force building the same product multiple times with no significant interruptions or pauses. Modern ship programs aren't like that. If these conditions are not fulfilled, there is discussion in the literature of loss of learning, but no closed-form, statistically-based method to predict how much learning is lost. One model, the Anderlohr Break-in-Production Model, quantifies the effects of production breaks, but requires expert opinion and is, therefore, not defensible—it is only useful when mutually agreed to by, e.g., the contractor and the contracting officer. In practice, this agreement is rare. In competition, or in cases of outside scrutiny, for example by the OSD CAIG, this method will almost certainly not stand up.

This problem seemed intractable, with no defensible methodology, until one graph changed everything; that single graph, one of many scatter plots, led to the breakthrough that started the ALM. In that graph, Vessel Labor and Time between Ship Deliveries (in the final version, start fabrication was used as the marker for ship construction interval) were jointly plotted by ship (this necessitated use of a dual-axis graph). From this one "Rosetta Stone" graphic, it became clear that MH rise and fall as time between ship starts rises and falls. We were not yet ready to assert a closed-form learning model, but we began to suspect that learning was continuing throughout the ship class, and perhaps being lost as well. The driving variable was ultimately expressed in terms of percent of build duration instead of days, as will be explained later. Many painstaking analytic steps remained, but the basic answer had begun to emerge.

The analysis took a number of steps, as we have said. It should be noted that nothing was easy in this analysis, since the data went back many years and, more often than not, was not available in the form in which it was needed. Accordingly, practically every step required data normalization using analytical constructs or some form of "decoding" or deconstructing. These steps were all done after careful consultation with people who were present and in responsible positions at the time of production, and are in accord with conventional wisdom. Most significantly, in the end the analysis works, so the steps are, to a point, justified. We say this knowing that, "the end does not justify the means"; nevertheless, when steps that make

sense are taken, and the result is both in accord with our ideas as to how it should be, and statistically verifiable, the result acts to shore up our confidence in the steps. With that warning, we will proceed with the description of the analysis.

1. First, we subtracted Type I change orders as listed in the contracts for each ship. These are changes requested by the Navy for new "content" on the ship.

2. Second, we removed change orders that were unseen originally because they were embedded in the base work of later ships. These change orders were no longer tracked in the tracking system, as the work they contained was "rolled into" the base contract.

3. Third, we took into account "Green Labor," adjusting the MH to what they would have been had the labor mix been a nominal mix of experienced and inexperienced labor. This third step removes ship-by-ship variability of the labor force mix.

4. Fourth, we adjusted for time between ship starts, as represented by the Start Fabrication step. This fourth step is the keystone to the analysis. The statistics for this step will be shown.

The first three steps were difficult to judge on a one-at-a-time basis since they were not statistically testable. As we have said, however, we assert that the final step, having been performed after the first three and tested as valid, acts to indicate (and we use this word advisedly) that the first three steps were valid. Had the fourth step failed, we would not know which step(s) to blame, but since it worked, and since all four steps conform with conventional wisdom on how these effects should work, we feel justified in claiming they all were valid. We did not rest on this claim, however, but conducted analysis on a second ship class and ascertained that our findings were neither a coincidence nor a result of "wishful analysis."

These steps as described result in a "peeled onion"—by "backing out" the various compounding effects to arrive at what turns out to be the smooth and continuous underlying learning curve. It should be noted that all steps can be reversed to constitute a cost-estimation model that relies on accurate plans for change orders, yard manning, and ship intervals, at least the last two of which can be derived from shipbuilding plans.

Analytical Details

Analysis for Step 1—Change Orders

Change orders were available for all ships, but only at the aggregate level. When these aggregated changes were removed, it was clear further analysis was needed. We knew from testimony that, at a certain point in the life of any class, change orders from prior ship contracts are "rolled into" the base contract; from this point forward, these change orders are not tracked separately from the base work. This led us directly to Step 2, embedded change orders.

Before we depart from step 1, however, we should note that *actual* VL MH for change orders are not tracked separately; so, only *estimated* change orders are available. There is considerable doubt among analysts as to the value of change orders, some believing that change orders are significantly overestimated (and, hence, a great source of revenue), others believing they are a significantly underestimated (and, hence, a loss). When this analysis was done, we emerged with the conviction that change orders are estimated quite well, else the analysis would never have held up; we urge analysts and decision-makers to consider change order estimates to be more accurate than they have in the past.

Analysis for Step 2—Embedded Change Orders

The removal of embedded changes required a great deal of decryption. Using the aggregate changes as a base, we segregated out one-time allowances for rip-out (removing completed or in-progress work that the change order replaces), disruption, and one-time change orders. We also had to apply learning to the change orders, because like any work, as units progress, MH decrease. Applying the normal percentage for each of these one-time effects, and applying learning, we "reverse engineered" to decode the change orders for follow-on ships.

With the ship-by-ship deconstructed change orders in hand, we were able to "see" what the change orders looked like and, thus, could see when the change orders were rolled into the basic contract. We were able to spot a distinct rise in base work and an offsetting drop in change orders on the same ship; we matched this detective work with the memories of senior shipyard personnel and with the contractual picture (changes in the base work could only happen at the start of a contract of multiple ships). The resulting embedded change orders were then subtracted from the appropriate ships; total changes were now removed.

Analysis for Step 3—Green Labor

"Green Labor" is defined as workers with less than 5 years experience; after 5 years, Green Labor becomes "Dry" or "Seasoned" Labor. Green Labor is less effective than Seasoned Labor, based upon a study conducted at Northrop Grumman Ship Systems at their Ingalls Operations, and as indicated by a percentage. (For example, if a worker is 80% effective, then it will take him or her 25% more hours to complete a task, since $1.0/0.8 = 1.25$.) This old study was not much in use, because it was perceived to be less than defensible since it was based upon expert (inside-yard) opinion. One of the benefits of our analysis was that we revitalized this model and gave it credibility, as we will discuss. The percentages by year probably differ with type of ship, yard, training programs, etc., as we know that the percentages are different at Northrop Grumman Newport News, based upon a study conducted there. For this analysis, we used a weighted average of effectiveness for workers in the first 5 years.

As in earlier steps, however, it wasn't just that easy. Data did not exist, for any unit, tracking the portion of the labor force that was green vs. the portion of the labor force that was dry. Again, we needed a construct. By interviewing managers and HR personnel, we ascertained the key variables in the experience-level problem, and built a Markov Chain model for labor experience. We know, for example, that layoffs were LIFO (last-in-first-out); we know the attrition rates for Seasoned and Green labor, and we know that most hired labor was Green. We built a Markov Chain model, and it produced the then-current labor mix within about 2 percentage points; the model was seeded with a reasonable start point, so we were confident that the Markov Chain labor mix estimates were close. This model gave us the year-by-year labor mix, and we used this mix to adjust to a notional (most common) labor mix, thereby nearly (because this is an approximation, we can only say "nearly") eliminating the effects of labor force mix.

As a side note, in past briefings we often said that the effects of labor mix are not dominant in this problem, because labor mix is fairly stable; after Hurricane Katrina, however, when we looked at reconstituting the labor force with this model, we saw that when labor swings considerably, the effect becomes quite big. In a small-business-base case, considerable cost impact is, in fact, caused by labor swings. While average Green Labor is less efficient than Seasoned Labor, first-year labor is *quite a bit* less efficient, so an unstable work force that is constantly ramping up and down will result in considerable loss of efficiency. This all said,

however, our model demonstrates that the potential for cost impacts are greatest in the last variable: loss of learning due to interval effect.

Analysis for Step 4—Loss of Learning due to Interval Effect

The final step is the most important step, both because the prior steps were either understood or in practice, and because this step acts to verify, in the way we have described, the earlier steps. In this step, we conducted a linear regression of the difference between learning as observed and learning as expected. Though this was difficult in derivation, and had many false steps, the result is intuitive.

Two major assumptions underlie our method. These two assumptions are in accord with current learning curve theory but deserve mention. First, we assumed that learning is constant and incremental and proceeds from one ship to the next. This means that as other effects occur, the learning curve factor is still at play. We have been surprised that others have asserted that learning stops after nine or ten ships[35]. This is not in consonance with anything in the literature of learning, and we believe that the results of this analysis bear out our belief that learning continues through all units. Getting ahead of ourselves for a moment, we believe that at some point in a ship class there is surely a considerable change-order effect and the attendant slow-down in production as the changes are engineered, which causes loss of learning. This is not to say learning stopped, but rather to say that other effects are causing a rise in ship costs. Some of these effects are controllable; and all are, to some degree, predictable. Second, we believe that should there be a loss of learning, (1) the learning begins anew, arguably at the same rate; and (2) it continues from the new point with later ships. Both things occurred in the two classes we analyzed. Said another way, loss of learning acts as a reset of the curve; later units will never revert to the *old curve*, but rather proceed from the reset unit following *a new curve with the old slope*. This last belief means that we must measure loss of learning from the effective unit of the prior ship, moved ahead one unit. Thus, we must correct out all other effects since those effects (or at least those we encountered) are either transient or fade on their own timescale. Green labor appears to be one such effect; as the labor force matures, workers approach a basic efficiency.

This discussion should by now have alerted the reader as to how complex this analysis is and how dependent it is on each step. Get one step wrong—we know, we did it many times as we groped through it—and the whole thing will not work. One can "see" the effects; to prove them analytically, however, requires considerable precision and care. It was particularly confounding that for many of the ships in the DDG class, the Green Labor and interval effects tended to counteract each other. This was because when time between ships stretched out— causing loss of learning due to interval effect, which tended to drive VL MH up—there was less work in the yard, so manning was reduced (largely via the firing of Green Labor), resulting in a more efficient labor force, which tended to drive VL MH down. At other times, such as at the onset of major changes in a class, the effects can reinforce each other because there has been a gap, but work then suddenly builds up in the yard. It was not until *both* effects were quantified that this complex interaction could be fully understood. This interplay has doubtless been a major complication in understanding these effects.

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[35] Arena, M.V., Blickstein, I., Younossi, O., Grammich., C.A. (2006). Why has the cost of Navy ships risen? A macroscopic examination of the trends in US Naval ship costs over the past several decades. RAND.

When conducting our analysis, we first determined to what point on the learning curve each ship should have progressed based on the previous ship. This was conducted iteratively from the second ship to the final ship. We then regressed the difference between the expectation and the realization, expressed as numbers of units (or fractions thereof) lost, against days between ships. The regression was significant at the 95% significance level (the "p-value" was 0.0106). The coefficient of determination (called r^2) was 0.4324. While this is not an overwhelming r^2, it is a respectable one, and in any event, the determinant of validity is significance, not r^2.

This regression shows that loss of learning is linear with days between ship starts. As ships are built less and less frequently, learning seems to "flatten." The underlying learning curve slope, however, continues to remain in force. The ships do not cease to learn, they lose learning. This is an important distinction. If the interval shortens, as it occasionally does, the MH drop faster, reverting to the original learning curve slope if they are close enough together.

There is much to discuss about this finding, but first we should observe one very important fact. The underlying learning that emerged for a ship class of 25 ships was the same learning realized by the first nine undisturbed ships. After the ninth ship, cost began to rise, so much so that the cost of the thirteenth ship was nearly equal to the cost of the fourth ship. This may not be surprising after all our descriptions of the effects that change costs. The point is that most of these effects do not happen in the early ships because they tend to be produced at steady, close, intervals; this proved true for both DDGs and LHDs. The rise that began in DDGs after nine ships (and in LHDs after four ships, though, like DDG, about five years into the program) was caused by the combined effects of change orders, embedded change orders, labor inefficiencies caused by the coincidence of a new class of large ship in the shipyard, and loss of learning due to the delays caused by the incorporation of a major change (DDG 51 Flight IIA). We are confident that this is why so many analysts in shipbuilding cite cessation of learning; but we wish to say this again for emphasis: learning continued in this ship class, as far as we had data, out past the 25th ship. The reader will see that this was true in LHDs as well. Costs rose due to predictable (or at least expected) effects, and, though learning was lost due to slowdowns, it continued on from each point "as regular as sunrise." To say learning stopped is to miss the point and to forsake the opportunity of prediction.

We also found that there appeared to be an "ideal" interval between ships that causes consistent learning. But as our understanding deepened, we began to appreciate that a ship class can seem to take any learning curve, depending on the predominant interval between ships. We will also show the days between ships was a poor way to display the interval, and we later changed to percent of construction duration; this change promises to open a whole new possibility. We will we discuss both things further below.

The Need for Confirmation: The LHD Class

The DDG model has been laid out. In many important analyses, it is customary to do second trials (e.g., in medical studies). The second test guards against spurious results. We will describe the meta-analysis later. In this case, though, a confirming analysis was needed more than in usual cost analysis cases because of the many data normalization steps that preceded the regression. We have asserted that the ultimate regression sustains the earlier steps, but we cannot escape being nervous that we may have driven towards a conclusion, inadvertently forcing the conclusion. This is natural and must be guarded against. Accordingly, we immediately set about repeating the analysis for a second ship class.

We did exactly the same analytical steps on the LHD as described for the DDG and arrived at exactly the same conclusions; we found the LHD class had done just what the DDGs did. The LHD step 4 regression for the Interval Effect was significant at the 95% significance level (the "p-value" was 0.017). The coefficient of determination (called r^2) was 0.887. This r^2 was higher, due simply to the fact that the LHDs fell into two groups; 3 units lost no learning and two lost all learning. Once again, the determinant of validity is significance, not r^2. The only difference was that the rate at which the LHDs lost learning was slower (the slope of the line was flatter); and the "cross-over" point, the interval at which there was no loss of learning at all, was longer in days (the x-intercept was greater). In a manner of speaking, the "time constants" were longer. What was more interesting, however, was that LHDs had on two occasions lost learning very dramatically; the class had reverted to a first unit (lost all learning) twice, at LHD 5 and LHD 7. The underlying learning for the LHD class was quite similar to the DDGs, only a few percentage points flatter. As a last caution, we know that two LHDs lost all learning and reverted to the first unit. We, thus, cannot know whether the interval effect might be stronger than we have evidence for because these two ships were capped at the first-unit level. Accordingly, we know that the LHD interval effect is at least as strong as we found, and quite likely stronger.

This brings us to an important point: learning due to interval, according to our model, occurs in units with time. For mature classes (say after nine ships, like the DDG), the loss of a few units is not a large number of MH, because the curve has flattened out by this point to a few percentage points per unit. For less mature classes, like the LHD, however, learning is still occurring at a steep rate, and the loss of a unit may be more on the order of 10% or more. In either case, if the Navy or the Coast Guard have negotiated an FPI contract, because "follow ship costs should be well known," and there is a delay due to negotiations, design activity, or lessened SCN budgets, the rise can erase all profit. This can be even more of a problem if the method of EAC computation does not catch an insidious rise in preceding ships, perhaps also due to factors that do not lie at the feet of the builder and which will cause the next ship to rise for additional (additive) reasons.

Meta-analysis and Mutual Confirmation

To summarize, the DDG model is, as far as statistics can take us, valid. The LHD model is also valid, and we can use either. The significance of the entire analysis is one minus the square of the significance of each: $1 - 0.05^2 = 1 - 0.0025$ (significance is 99.75%.) This well-known technique is called meta-analysis. Most importantly though, the LHD model represents a second ship class and was undertaken to confirm the DDG model. Taken together, the LHD and DDG models are much stronger than either is alone because the models are mutually confirming. Taken alone, the DDG analysis has the weaknesses that "first models" commonly have: although reasonable, the adjustments were taken to drive towards a smooth learning curve. Statistically, this amounts to an uncredited loss of "degrees of freedom." Alternatively, a hostile view can arise that the data was "cooked." The LHD model alleviates this concern. Since the steps taken with DDG were replicated in LHD and the same result was obtained, our analysis was neither dumb luck nor manipulation. Further, the LHD class had only 7 ships completed, so taken alone, the LHD analysis lacks data across the full spectrum of interval length. The DDG model alleviates this concern with 25 ships and a wide range of intervals.

ALM 2: The Enterprise Model

We built an enterprise-level model that instantiates the Advanced Learning Model for an entire shipyard complex, namely Northrop Grumman Ship Systems. We call this a forward-looking model because it projects effects given the results of the prior analysis, which we call ALM 1. This model, called ALM 2, brought about three significant new capabilities. First, the model allows for the quick determination of the impacts of the effects described above on either a future ship class or the remainder of a class. It also allows the input of all ships in the enterprise. Second, it computes the labor profile, at the gross level, for the yard—a capability which formerly took weeks. The detailed trade-by-trade labor profiles are still done by hand, and much mischief can arise at the trade level that the enterprise model is blind to; but, large what-ifs can nevertheless be done quickly as a first-order approximation. Third, this enterprise model has the ability to model cross-ship effects and, since it is in closed form, feedback effects on labor.

When a ship cost estimate is done, the apparent labor needs are determined for a notional labor profile—the profile that was in effect at the time of the historical data. The model first needs to compute the efficiency of the labor force in the yard where it is being built based on the mix of Green Labor. The model then will compute interval effects based on the preceding ship and the interval before the ship in question. At this point, the model will adjust the need for labor. This adjustment changes the labor mix in the yard because new labor must be hired above (or below) what was expected, due to the effects of these two variables. This produces a feedback loop which happily converges fairly quickly. Likewise, the model, having all ships in the yard loaded in, quickly computes the effects of the new labor on all the other ships in the yard as the labor force, and the associated feedback loops, swells or shrinks and does so quickly.

The enterprise model brought out an understanding that is worthy of some discussion. As we began to use the model to predict ships, we needed to develop a good prediction for change orders. When we did the analysis using the carefully deconstructed change order data for these two ship classes, we were taken aback by the size and the implications of what we found. We found that change orders were large on the first ship, which we had known, and averaged 12.30% of base costs (with a wide variability). We knew that by definition change orders would be large at Flight change or at major modifications, so when we found that changes were 8.62% of cost it was sobering but not surprising. What surprised us was that change orders on the rest of the ships, ships that were neither first ships nor major modifications, was 2.97%, with a fairly clear pattern of rising over the class but virtually always exceeding 1.2%. This change-order pattern meant that by the 25th ship, with two major modifications, the labor cost of the DDG change orders had have become equal to about half that of the base ship. On the LHD, change orders have risen to be about one-quarter of the cost of the base work by the 7th ship. This finding showed us that change orders are a much larger part of the cost of follow ships than we had realized, even though we knew the conventional wisdom that changes are a big factor in ship costs.

It should not be concluded that change orders are inherently bad. Change orders are at least partly a response to lessons learned, changes in technology and in the threat. That said, they bear careful monitoring due to their size, which begins to rival initial cost in their claim on scarce SCN. Change orders also have a second, hitherto-less-well-understood effect on ship costs. It is quite likely that change orders act both as chicken and egg in the ship-cost scenario. As budgets drop, interval increases, allowing an ever-increasing pressure for change—be it due to an industrious engineering community, technology changes, or requirements changes.

Conversely, changes cause design delay, increasing intervals, sometimes considerably, as they do in major modifications. Thus, changes are already a considerable factor and have the ability to become more of a factor in tight budget years, as well as to drive the other effects to become larger as they delay ships and contribute to cost rises—which destabilize labor costs.

Implications

At the outset of this paper, we described how ship costs have suddenly seemed to go out of control just as budgets have dropped, exacerbating the problem. There are no doubt many reasons for such a problem, some of which are outlined in the RAND study already referenced. Many of the reasons cited in the RAND paper, such as inflation and commodity volatility, have conventional means of prediction, however flawed the results may be. Our paper, on the other hand, puts forward three new effects that were hitherto generally ignored analytically or discounted by decision-makers. As we have already said, change-order estimates in general turned out to be quite accurate; without this accuracy, the analysis would have been impossible. The "lost" change orders are unarguable in principle, and although the exact values estimated could be quibbled with, they are certainly "generally right." The illumination we have brought to this issue will help explain past cost increases. And closer attention to tracking change orders going forward should be a big help to future cost estimation. The Green Labor model we described was in use at one Northrop Grumman shipyard and is now in use at them all, although its impact is debated and occasionally somewhat discounted. We believe that Green Labor's part in this analysis will go far to bolster the basis for the computation of this effect. The interval effect has always been part of shipyard lore, but has never been quantified. Even now, shipyards are struggling to understand the model and to overcome past "explanations" for rising costs, such as: labor inefficiencies (true, but overstated for the lack of an agreed-upon model), one-time events (again, true, but arguably overstated for lack of sufficiently reliable discrete cost tracking), and disruption effects such as were alleged to have happened twice on DDG and once on LHD (we found no significant differences that needed explanation, so the supposed disruption, although appealing intellectually, was absent if you believe our analysis).

The net of the effects in this paper is extremely large, and almost all was cost growth. The _newly explained_ cost growth in labor, resulting from embedded change orders, Green Labor and loss of learning due to interval for all ships from 12 through 25 of the DDG is a total of 21%, and for all ships from 3 through 7 of the LHD is a total of 19%. This is a staggering amount of cost to have been hitherto unexplained. Of the newly explained cost growth in labor, 8.8% (almost half) of the growth in DDGs was from loss of learning due to the interval effect; for the LHD class, 14% (almost ¾) was from loss of learning due to the interval effect. Most of the rest of the unexplained cost growth was due to "lost" change orders. The DDG interval effect was less of the total partly because the class was more mature and further down the learning curve; thus, units lost were smaller in MH than for LHDs. Conversely, for LHDs, change orders were less of the total because there had been fewer units for them to have accumulated. Green labor was the least of the effects, and tended to be pluses or minuses as labor waxed and waned. We thus believe that a large mystery has been solved, and that we have provided the ability to avoid similar large errors in the future. As with any cost-estimating technique, of course, the ability to project will depend upon how well we can determine the inputs.

This model has the capability to account for many large and unpleasant cost-growth effects, especially for modified ships that are characterized by long intervals, large change-order packages, and large swings in labor as the class goes back into production. Hence, we believe

that the model will be invaluable in better predicting costs. We hope it will be helpful in reducing mistrust and tension between the Navy and the Coast Guard on the one hand, and the shipyards on the other—as well as between the Congress and the services. We believe the model goes a long way towards explaining cost rises in terms the various parties can better understand as unavoidable in the past and more predictable in the future.

There are policy implications to these findings as well. We believe costs can be better estimated now; but beyond that, they can be better controlled as well. One simple exercise involved changing the acquisition profile for Large Deck Amphibious ships. By optimizing the timing of ship acquisitions, we found that labor costs could be reduced by almost 6% in constant dollars—and this was with only a single ship class to work with. In addition, in order to be successful, the Navy's current cost reduction strategy of re-using existing hull forms for new classes of ships must obey the constraints illuminated here. Change orders must be suppressed to the degree that they can, intervals between ships must be thoughtfully timed, and demand variance that results in workforce instability must be avoided. We note that this is consistent with an enterprise view of shipbuilding: the Navy making acquisition decisions that support its private-industry partners in their efforts to contain costs. On the other hand, for the Navy to pursue acquisition strategies that ignore the demonstrated effects of change orders, loss of learning due to interval, and Green Labor—and at the same time to press for cost reduction—is inherently problematic. It is further setting the enterprise up for failure.

Next Steps

We hope to take this analysis to other ship classes. We further hope to take it beyond ships to other commodities. As strange as it may sound, application to satellites is quite promising, as they are, like ships, complex objects with long development spans involving integration of many components, operated in demanding environments, and procured in small "batches" (usually one or two). There is no clear reason why this methodology should not work for other sorts of production. Indeed, the problem may be considerably easier since labor force changes should be less of an effect in items of shorter duration and higher production rate. Change orders may also be easier, because data will not be so old in calendar terms and since the shorter times lend themselves to fewer changes.

We would like to point out that so-called "rate effects" in learning have been elusive. We know of no demonstration of a statistically significant rate effect. We suggest that perhaps the "rate effect," which is commonly introduced as a second term in the learning equation, may simply be an incorrect portrayal of the interval effect we have demonstrated. Rate effect uses the number of units to be produced in a given year and lowers costs as the quantity rises and raises costs as it drops. This acts to reduce cost when units are built closer together (more production units per unit time), thus mirroring the sense of the interval effect we found but using different mathematical expressions to model it. Statistics have the unfortunate limitation that a hypothesis must be formulated for the test. If the hypothesis is structured in an incorrect form, the model is unlikely to be significant; thus, the hypothesis that the model is invalid cannot be rejected. Many good ideas founder on this shoal, and this failure of an "almost right model" or a model that acts in a sensible way, but is formulated a bit incorrectly, frustrates the analyst and leads to unreasonable distrust of statistics. We look forward to investigating the rate effect relative to the interval effect and believe that the interval effect will replace it in practice.

As we have alluded to, we have already begun a re-formulation of the model. We have changed the expression of the model for loss of learning from days to percent of construction duration. This is merely a change in scale, and the results do not change for either model.

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What does change, however, is that when the model is expressed in the new way, we discover that the LHD and DDG graphs of loss of learning overlay each other. In the "days form," we had no way to move to another class, because we had no way to interpolate save linearly, and we were wary of this assumption. Worse yet, when applied to a much smaller ship, like a frigate, or a much larger ship, like an aircraft carrier, the extrapolation became irrational. This amounted to *reductio ad absurdum* of linear extrapolation and so cast doubt upon interpolation. When expressed as percent of interval, however, the result, although not yet tested, is appealing and intuitive. This version of the model is called ALM 3.

We are not shipbuilders, and further, we are always reluctant to speculate beyond what we can prove. Nonetheless, one of the reasons we are inclined to believe this "percent form" is that the nature of work on a large ship changes less quickly during production than for small ships. For example, shell plating and other large-object welding lasts a similar percentage of construction time on large ships as it does for smaller ships; hence, we speculate that the opportunity to "learn" lasts longer, and time to lose it takes longer in days but not in percent.

This change in scale has taken us to another point. We are in the midst of trying to determine whether the percent model will lead us to a long-sought capability: the capability to predict the underlying learning curve for any ship knowing only the expected construction duration and the planned schedule for the class. We anticipate having a preliminary version of this in time for the symposium, or to have learned that this is un-doable. If we can achieve this, we feel the results will be every bit as important as the loss-of-learning model. It would also increase the importance of both accurate schedule estimating and stable program schedules, as these are key inputs to the learning-curve determination, which in turn is the single biggest driver of labor cost. It is premature to make a claim of broader application, especially since the ship portion is as yet undone, but we cannot stop our minds from racing ahead. We hold out hope for this model being useful in other commodities. We have, on an informal basis, noted that the interval for Global Hawk is similar to that for DDGs in percent, and that the learning curve is similar. We raise this point in order to excite the reader's interest and to indicate that the possibility of further application is real.

Conclusions

This paper is short, and so our conclusions should be short as well. We have shown that a careful treatment of change orders, labor force mix, and time between ship starts has enabled us to demonstrate—we believe for the first time—a closed-form and statistically rigorous treatment of loss of learning. The analysis has validated an old labor mix model and shown it to have considerably credibility, and has unified change orders, labor profiles, and loss of learning in a way that substantially changes ship-cost estimation. We have already created an enterprise model and have hopes of being able to extend the model to other commodities. We will, perhaps, even be able to predict learning curves for ship classes—a capability that does not yet exist.

Panel 18 - Modeling & Simulation in Support of Acquisition

Thursday, May 17, 2007	Panel 18 - Modeling & Simulation in Support of Acquisition

1:45 p.m. – 3:15 p.m.	**Chair:**
	
	    Daniel A. Nussbaum, Professor, Naval Postgraduate School
	
	Papers:
	
	Simulation Based Acquisition Revisited
	
	    Michael F. McGrath, Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation
	
	An Innovative Approach for Training Acquisitions—Part II
	
	    Fred Hartman, Deputy Director, Readiness and Training, and Director of the Joint Assessment and Enabling Capability, Office of the Under Secretary of Defense for Personnel and Readiness
	
	An Open Strategy for the Acquisition of Models and Simulations
	
	    Rudy Darken, Naval Postgraduate School
	
	Application of Systmes Engineering Principles in Curricular Design
	
	    David H. Olwell, Jarema M. Didoszak, Jean M. Catalano, Naval Postgraduate School, and **LCDR Joseph Cohn**, USN, Medical Service Corps

Chair: Daniel A. Nussbaum, PhD is a Professor at the Naval Postgraduate School, in the Operations Research department, in Monterey, California. His expertise is in cost/benefit analyses, life cycle cost estimating and modeling, budget preparation and justification, performance measurement and earned value management (EVM), activity based costing (ABC) and Total Cost of Ownership (TCO) analyses.

From December 1999 through June 2004 he was a Principal with Booz Allen Hamilton, providing estimating and analysis services to senior levels of the US Federal government. He has been the chief advisor to the Secretary of Navy on all aspects of cost estimating and analysis throughout the Navy, and has held other management and analysis positions with the US Army and Navy, in this country and in Europe.

In a prior life, he was a tenured university faculty member.

Dr. Nussbaum has a BA, in Mathematics and Economics from Columbia University, and a Ph.D., in Mathematics from Michigan State University. He has held post doctoral positions in Econometrics and Operations Research, and in National Security Studies at Washington State University and Harvard University.

He is active in professional societies, currently serving as the President of the Society of Cost Estimating and Analysis. He has previously been the VP of the Washington chapter of INFORMS, and he has served on the Board of the Military Operations Research Society.

He publishes and speaks regularly before professional audiences.

Finally, he is married, has two children and four grandchildren. He is a lap swimmer and a dedicated herb and vegetable gardener.

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Simulation Based Acquisition Revisited

Presenter: Michael F. McGrath, Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation. Dr. Michael McGrath is the Deputy Assistant Secretary of the Navy for Research, Development, Test and Evaluation. His role is to develop programs to bridge the gap in transitioning from Science and Technology to Acquisition, and to improve processes for integrating T&E across acquisition programs. Prior to his appointment to this position in 2003, Dr. McGrath spent five years as Vice President for Government Business at the Sarnoff Corporation, a leading R&D company with both commercial and government clients. Dr. McGrath has 28 years of prior government experience, including logistics at NAVAIR in the 1970s, acquisition in OSD in the 1980s, and technology development at DARPA in the 1990s. Dr. McGrath holds a BS in Space Science and Applied Physics, a MS in Aerospace Engineering, and a doctorate in Operations Research from George Washington University.

An Innovative Approach for Training Acquisitions—Part II

Presenter: Fred Hartman, Deputy Director, Readiness and Training, and Director of the Joint Assessment and Enabling Capability, Office of the Under Secretary of Defense for Personnel and Readiness. Hartman is a distinguished member of the DoD M&S Community, and has served for many years in various government and industry positions. He is currently the Deputy Director of Readiness and Training Policy and Programs (RTPP) for the Office of the Under Secretary of Defense, (Personnel and Readiness) and the Director of Training Transformation Joint Assessment and Enabling Capability (JAEC). Mr. Hartman also serves as a tri-chair and Training Community member for the DoD M&S Steering Committee.

Mr. Hartman was commissioned in Field Artillery on graduation from the United States Military Academy and later earned a Master of Science degree in Operations Analysis from the Naval Postgraduate School. In addition to FA and Aviation assignments, he served as: military operations analyst, procurement programs analyst, executive assistant and analyst for the Deputy Under Secretary of the Army for Operations Research.

After his Army career, Mr. Hartman was an Executive Vice President for CACI. He also served as Chief Operating Officer, co-founder and board member for Applied Solutions International, Inc. In 1995, Mr. Hartman joined the Institute for Defense Analyses as a modeling and simulation consultant to the Deputy Under Secretary of Defense for Readiness. In 2004, he assumed duties as Director of the Joint Assessment and Enabling Capability and, in 2005, took on the additional responsibilities as Deputy Director of RTPP. Mr. Hartman has served as a member of the Army Science Board, led a study panel for the National Academy of Sciences Board on Army Science and Technology and is a past president and fellow of the Military Operations Research Society.

Abstract

The Training Capabilities Analysis of Alternatives (TC AoA) published in 2004 examined a host of issues related to training transformation and the future of training to meet joint operational needs. During the conduct of the TC AoA, the industry partners participating in a business game indicated the DoD should improve their approach for buying training simulations and tools as well training support services. The AoA recommended a limited acquisition prototype (known as Alternative #4) to explore the many issues for procurement of training, including privatization of both training-support and training-tool development efforts with competitive market forces. The RAND Corporation conducted a follow-on research effort in 2005 to produce and implement an evaluation plan for the prototype of this alternative. The current prototype is being executed this year to include the Defense and Inter-agency Coordination for Homeland Defense training issues.

This presentation should be of interest to those participating in, or charged with carrying out, innovative approaches for Defense Acquisitions, including Modeling and Simulation. After a short update on the training community progress on the Alternative #4 business process, the common and cross-cutting aspects of this prototype from training to other functional DoD applications will be discussed.

An Open Strategy for the Acquisition of Models and Simulations

Presenter: Rudolph Darken, Director, the MOVES Institute, Naval Postgraduate School. Darken is the Director of the Defense Modeling and Simulation Institute (MOVES) and Professor of Computer Science at the Naval Postgraduate School in Monterey, California. He is also the Associate Director for Research for the Center for Homeland Defense and Security and serves on the Academic Committees for Modeling and Simulation (MOVES) as well as Human Systems Integration (HSI). His personal research has been primarily focused on human factors and training using virtual environments and computer gaming media with emphasis on navigation and wayfinding in large-scale virtual worlds. He is a Senior Editor of *PRESENCE Journal*, the MIT Press journal of teleoperators and virtual environments. He received his BS in Computer Science Engineering from the University of Illinois at Chicago in 1990 and his MS and DSc degrees in Computer Science from The George Washington University in 1993 and 1995, respectively.

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Abstract

It remains unknown exactly how much the Department of Defense spends on Modeling and Simulation annually. Estimates range from $9B to $15B, but precise numbers are unavailable because it's hard to say where M&S starts and ends in a training, analysis, or acquisition program. But if these estimates are anywhere near accurate, a discussion of how we acquire M&S capabilities and how we can get more done with less is warranted. The DoD has recently approved the equal consideration of open source for supplying software for DoD functions. M&S, being largely a software-based technology, should fall under this policy. However, M&S remains an almost exclusively proprietary domain for software development— even though the commonalities between M&S products are vast. The simple fact is that the current model for the acquisition of M&S products requires that the government pay for the same capabilities over and over because reusability is not considered, or at least not considered to be possible or practical. This is a myth. There are good examples in which this is changing— for example, reusable terrain databases in aviation simulation. The saving here are enormous. But more M&S products are bought and paid for as complete products, where the supplier is virtually guaranteed downstream revenue due to "vendor lock-in" common in software products. There is a way out. An open source and standards framework to simulation that modularizes M&S software so that the government buys only what it needs is possible. In fact, we have an excellent example of such a framework from enterprise computing called the Service Oriented Architecture (SOA). This presentation will introduce concepts of open source and standards for the Defense M&S community and will show how a SOA approach (but not a literal SOA implementation) is possible and can result in extremely large efficiency gains due to reusable software, content, and source code.

Application of Systems Engineering Principles in Curricular Design

Presenter: David H. Olwell is the Chairman of the Department of Systems Engineering at the Naval Postgraduate School. Dr. Olwell previously taught at the United States Military Academy in the Department of Mathematical Sciences and in the Operations Research Department at the Naval Postgraduate School.   His specific research interests focus on the analysis of systems, with emphasis on reliability, quality, and warranty issues.

Author: Jarema M. Didoszak is a Research Assistant Professor in the Mechanical and Astronautical Engineering Department at the Naval Postgraduate School, Monterey, California. Mr. Didoszak is also an engineering duty officer in the Navy Reserve. Over the last four years, he has been conducting NAVSEA-funded modeling and simulation research in support of the DDG 81, LPD 17, DDG 1000 and LCS ship shock trial programs. He is currently pursuing a PhD in Mechanical Engineering.

Author: Jean M. Catalano is a Research Assistant in the Systems Engineering Department at the Naval Postgraduate School, Monterey, California. After serving on active duty in the US Navy, she supported the NAVSEA Warfare Systems Engineering Directorate (NAVSEA06) before coming to Naval Postgraduate School, where she is currently pursuing a PhD in Software Engineering.

Authors: LCDR Joseph Cohn, USN, Medical Service Corps, is an Aerospace Experimental Psychologist in the US Navy's Medical Service Corps. He has served as the Lead Scientist on a range of training programs, overseeing the design, development, validation and transition of numerous Virtual Environment training systems across the DoN. He is currently serving as the Lead Scientist as part of the Chief of Naval Personnel's Strategic Concepts group, focusing on defining future challenges and solutions to Navy Manpower, Personnel, Training and Education.

Abstract

The Defense Modeling and Simulation Coordination Office presented the Naval Postgraduate School with an enormous challenge in 2006: design and deliver an educational program by 2008, for 20,000 or more acquisition professionals, focusing on the effective use of modeling and simulation in acquisition. The acquisition workforce is central to force transformation, and education is the key to transforming that workforce. This paper describes the processes, lessons learned to date, and assessment plan for this project.

We applied a systems-engineering approach to the problem of curricular design. The resulting solution consists of four spirals. The first spiral focused on defining the problem. We developed our analysis based on factors such as the market segmentation of the acquisition workforce, the current resources available, the state of the modeling and simulation body of knowledge, the desired educational outcomes for each market segment, and the gaps that existed between those outcomes and the existing resources. At each step in the process, we involved key stakeholders from the acquisition, test and evaluation and training communities. We describe the results of this process.

In the second spiral, our goal is to construct a learning architecture to cover the gaps identified in the first spiral. We describe the course content, scope, and delivery methods that are proposed based on those needs from the first spiral.

The results of the first spiral, initiation of spiral two and subsequent lessons learned, will be the focus of our discussion herein. We will also briefly summarize the third and fourth spirals, which involve course design and testing in spiral three and delivery and assessment of the curriculum for spiral four.

Keywords: Modeling & Simulation, Education, Acquisition, Systems Engineering.

Panel 19 - Acquisition of Services

Thursday, May 17, 2007	Panel 19 - Modeling & Simulation in Support of Acquisition
1:45 p.m. – 5:00 p.m.	**Chair:** **Stuart A. Hazlett**, Deputy Director for Strategic Sourcing, Defense Procurement and Acquisition Policy, **Papers:** ***Enterprise Challenges Facing the Strategic Sourcing of Services*** **Stuart Hazlett**, Deputy Director, Strategic Sourcing, Defense Procurement and Acquisition Policy ***The Commander of Naval Installations and the Acquisition of Services*** **Thomas Trump**, Assistant Deputy Commander for Contracting Management, Naval Supply Systems Command ***Performing Quality Assurance and Effectively Administering the Strategic Sourcing of Services*** **COL Anthony Incorvati,** Chief, BTA Division and Strategic Sourcing, ITEC4, Army Contracting Agency ***Essential Elements to Successful Execution of Strategically Sourced Services*** **Randall McFadden**, Director, Acquisition Management and Integration Center ***Delivering to the Warfighter*** **Dale Huegen**, Deputy Chief, Command Acquisition, USTRANSCOM ***Managing the Service Supply Chain in DoD: Implications for the Program Management Infrastructure*** **Rene Rendon** and **Uday Apte**, Naval Postgraduate School

Chair: Stuart A. Hazlett, Deputy Director for Strategic Sourcing, Defense Procurement and Acquisition Policy, serves as an advisor to the Director, Defense Procurement and Acquisition Policy (DPAP) and his staff on matters relating to the Acquisition and Sourcing Processes and initiatives across the Department of Defense. Mr. Hazlett provides advice and counsel regarding the formulation and development of policy on various strategic sourcing programs associated with transformation, and leads a focused team that oversees critical Acquisition, Technology & Logistics (AT&L) transformation initiatives that accelerate delivery of effective and efficient business mission functions.

Before taking his current position, Mr. Hazlett was the Chief of Procurement Transformation, Office of the Deputy Assistant Secretary for Contracting, Assistant Secretary of the Air Force for Acquisition, Headquarters U.S. Air Force, where he was charged with improving agile sourcing in the Air Force. His office maintained a contracting strategic management framework to identify, develop, and field strategic

initiatives to support a contracting enterprise responsible for executing $61B annually. Mr. Hazlett entered federal service in 1984 as a Pacer Produce assigned to the San Antonio Air Logistics Center at Kelly Air Force Base, Texas, and has held contracting offer warrants in the areas of research and development, systems, and sustainment acquisitions in support of numerous major weapons systems. During his career, he has served in direct support of congressionally mandated panels dealing with acquisition issues facing the federal government.

Mr. Hazlett holds a Bachelor of Arts degree from Ohio Northern University and a master's degree from Central Michigan University. He is also a 1998 graduate of the Industrial College of the Armed Forces, where he earned a second masters degree in national resource management. In addition, he is a graduate of the Defense Systems Management College at Fort Belvoir, Senior Executive Fellows Program from the Kennedy School of Government at Harvard University, and Leadership for a Democratic Society from the Federal Executive Institute.

Mr. Hazlett was recently honored with the Department of the Air Force's Award for Meritorious Civilian Service. He is married and has two children.

Enterprise Challenges Facing the Strategic Sourcing of Services

Presenter: Stuart Hazlett, Deputy Director for Strategic Sourcing, Defense Procurement and Acquisition Policy

The Commander of Naval Installations and the Acquisition of Services

Presenter: Thomas Trump, Assistant Deputy Commander for Contracting Management, Naval Supply Systems Command

Performing Quality Assurance and Effectively Administering the Strategic Sourcing of Services

Presenter: COL Anthony Incorvati, Chief, BTA Division and Strategic Sourcing, ITEC4, Army Contracting Agency

Essential Elements to Successful Execution of Strategically Sourced Services

Presenter: Randall McFadden, Director, Acquisition Management and Integration Center

Delivering to the Warfighter

Presenter: Dale Huegen, Deputy Chief, Command Acquisition, USTRANSCOM

Managing the Service Supply Chain in Department of Defense: Implications for the Program Management Infrastructure

Presenter: Rene G. Rendon is on the faculty of the Naval Postgraduate School where he teaches graduate acquisition and contract management courses. Prior to his appointment at the Naval Postgraduate School, he served for more than 22 years as an acquisition and contracting officer in the United States Air Force. His Air Force career included assignments as a contracting officer for major space launch systems and satellite programs, as well as the F-22 Advanced Tactical Fighter and the Peacekeeper ICBM. Rendon also served as a contracting squadron commander, and as a contracts manager for the NCR Corporation. He has earned Bachelor, Master's, and Doctorate degrees in business administration and has taught for the UCLA Government Contracts program and was also a senior faculty member for the Keller Graduate School of Management.

Author: Uday Apte, is Professor of Operations Management, Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA, and Associate Professor, Cox School of Business, Southern Methodist University, Dallas, TX. He teaches operations management courses in the Executive and Full-time MBA programs. His areas of expertise and research interests are in service operations, supply chain management and globalization of information-intensive services.
Prior to joining the Cox School, he worked for over ten years in managing information technology and operations functions in the financial services and utility industries. Since then he has consulted with several major US corporations and international organizations including IBM, Texas Instruments, Nokia, Kinko's, Nationwide Insurance, Nations Bank and The World Bank.

He holds a PhD in Decision Sciences from the Wharton School, University of Pennsylvania, where he taught in the MBA and undergraduate business programs for over ten years. His earlier academic background includes a MBA from the Asian Institute of Management, Manila, Philippines, and Bachelor of Technology from the Indian Institute of Technology, Bombay, India.

Dr. Apte has published over 30 articles, five of which have won awards from professional societies. His research articles have been published in prestigious journals including, Management Science, Journal of Operations Management, Decision Sciences, IIE Transactions, Interfaces, and MIS Quarterly. He has co-authored one book, Manufacturing Automation and has completed work on another co-authored book, Managing in the Information Economy.

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Introduction

The services acquisition volume in the US Department of Defense (DoD) has continued to increase in scope and dollars in the past decade. In fact, in recent years, the DoD has spent more on services than on supplies, equipment and goods, even considering the high value of weapon systems and large military items (Camm, Blickstein & Venzor, 2004). Between FY 1999 to FY 2003, the DoD's spending on services increased by 66%; and in FY 2003, the DoD spent over $118 billion (or approximately 57% of total DoD procurement dollars) on services (GAO, 2005a). The acquired services presently cover a very broad set of service activities, including: professional, administrative, and management support; construction, repair, and maintenance of facilities and equipment; information technology; research and development, and medical care.

As the DoD's services acquisition volume continues to increase in scope and dollars, the agency must give greater attention to proper acquisition planning, adequate requirements definition, sufficient price evaluation, and proper contractor oversight (GAO, 2002).

In our previous exploratory research on the challenges and opportunities in service supply chains in the DoD (Apte, Ferrer, Lewis & Rendon, 2006), we reached the following preliminary, yet significant conclusions:

- A continued growth in the volume and scope of service acquisition in the DoD in the future

- As observed at the Presidio of Monterey, innovative supply-chain arrangement involving synergistic contractual relations with cities adjacent to bases for the management of routine municipal services can result in significant cost savings.

- As observed at Travis AFB, settings conducive to successful service contracts include: (1) proactive and frequent communications among cross-functional teams composed of contracting personnel and personnel from the functional organizations involved as customers in the services contracts, and (2) co-location of contracting professional with the customers of services.

- Acquisition of services is more challenging in comparison with product/system acquisition since it is generally more difficult to establish service specifications and measure and monitor service output and quality. Hence, having onboard the right number of skilled acquisition personnel is highly critical. However, the observed downsizing of contracting workforce does not appear to be in line with this need.

- Although the DoD spends more on acquiring services than goods, the program management infrastructure for the acquisition of services is less developed than that for the acquisition of products and systems. In many service acquisition programs, a trained and dedicated program manager and programs management team does not exist, and the services contracting officer becomes the de-facto program manager.

The lack of a developed program management infrastructure for the acquisition of services is a critical research finding that warrants further study. Review of the current literature shows that the use of a well-defined, disciplined approach and infrastructure for the management of projects is critical for a project's success in meeting cost, schedule, and performance objectives (Kerzner, 2006). In the absence of a well-defined management infrastructure, project teams are left to create an ad hoc approach to managing the project. Based on our exploratory research, we believe that this is the current situation in many DoD services acquisition programs. The lack of a well-defined program management infrastructure and the lack of a lifecycle approach to the management of services acquisition projects is

putting the success of these critical services at risk. The risks for not meeting cost, schedule, and performance objectives are consequently higher in the DoD services acquisition sector. As the DoD increases its acquisition of services, particularly in light of anticipated budget cuts and dwindling resources, the DoD must ensure that its service acquisition projects are effectively and efficiently managed.

The purpose of this research is to continue our exploration in the area of services contracts while focusing on the implications of applying a program management structure to services acquisition.   We will first discuss some continuing issues in services acquisition based on our initial research and recent GAO reports. We will also discuss the uniqueness of services and how they affect the services acquisition process. Next, we will discuss some basic concepts of program management and then discuss how these concepts are currently being used in the acquisition of systems and products, specifically defense weapon systems. We will then discuss the application of program management and project management concepts to services acquisition; and finally, we will illustrate how program management concepts can be effectively applied at the various levels of the DoD to successfully manage service acquisition programs.

Continuing Issues in Services Acquisition

a. Conclusions from the Prior Research

As mentioned before, last year we conducted an exploratory research in Service Supply Chain in the Department of Defense. The conclusions of that research are stated below. We want to clarify that given the exploratory nature of that research, the observations and conclusions listed below are somewhat preliminary in nature, and should be viewed as such.

1. The Department of Defense's services acquisition volume has continued to increase in scope and dollars in the past decade. The GAO (2005) found that since FY 1999, the DoD's spending on services has increased by 66%; and in FY 2003, the DoD spent over $118 billion (or approximately 57% of total DoD's procurement dollars) on services. DoD procures a variety of services, including both the traditional commercial service and services unique to defense. In terms of amount spent, four service categories represent over 50% of total spending on services: (a) professional, administrative, and management support services, (b) construction, repair and maintenance of structure and facilities, (c) equipment maintenance, and (d) information technology services.

2. Presidio of Monterey (POM) has contracted maintenance of about 155 buildings and structures to Presidio Municipal Services Agency (PMSA), a consortium of the cities of Monterey and Seaside. The PMSA agreement has allowed the two cities to apply their expertise to routine municipal services and the Army to focus on its military mission. Through this partnership and contract with PMSA, the POM has realized a 41% reduction in expenses when compared with previous base operation costs and private contracts. We recommend the DoD explore and evaluate the possibility of establishing such synergistic contractual relations with cities adjacent to other bases for support of their respective operations.

3. Proactive and frequent communications are essential for a successful services contract. We found a successful example of this at Travis AFB, where 60th CONS uses BRAGs as the mechanism for conducting such communications. Business Requirement Advisory Groups (BRAGs) are teams made up of cross-functional personnel that represent the functional organizations involved as customers in the services contracts. These cross-functional teams plan and manage the service contracts throughout the service's

lifecycle. As the DoD increases the use of centralized contracting organizations and regional contracts, the use of proactive and frequent communications will be even more essential for the successful management and performance of these contracts.

4. Our visits and interviews at Travis AFB, Presidio of Monterey (POM), Naval Air Station Whidbey Island (NAS WI), and the Naval Support Detachment Monterey (NSDM) confirmed the GAO's finding that, "while the Army's and Navy's creation of centralized installation management agencies can potentially create efficiencies and improve the management of the facilities through streamlining and consolidation, implementation of these plans has so far met with mixed results in quality and level of support provided to activities and installations" (GAO, 2005b).

5. The centralization of contracting offices and use of regional contracts will result in additional dynamics to the DoD's acquisition of services. The use of centralized contracting organizations and regional contracts will require even more proactive and frequent communications between the contracting organization and the customer. Although it is still too early to assess the effectiveness and efficiency of centralized contracting organizations and regional contracts, this research has indicated that centralization and regionalization of services contracts are growing trends in the DoD and will significantly change how services contracts are managed.

6. Given the unique characteristics of services (such as intangibility, co-production, diversity and complexity), establishing service specifications and measuring and monitoring the quality of delivered service is inherently more complex than when dealing with manufactured goods. Hence, it is critical to have onboard a "knowledgeable client" and the necessary number of skilled contracting personnel to define the requirements and to supervise outsourced services. The DoD has been aggressively complying with OMB's Circular *A-76*, which directs all federal government agencies "to rely on the private sector for needed commercial activities." This has resulted in dramatic growth in the DoD's spending and in the downsizing of the DoD civilian and military acquisition workforce. Although this exploratory study is not yet completed, we believe that the above two trends contradict the critical need to have onboard a necessary number of skilled contracting personnel. This could mean that in the DoD's outsourced services, either the needs are not being fully satisfied, or the value for the money spent is not being realized.

7. Although the DoD acquires more services than goods, and the acquisition of services and the use of service contractors are becoming an increasingly critical aspect of the DoD mission, the management infrastructure for the acquisition of services is less developed than for the acquisition of products and systems. There is a less formal program management approach and lifecycle methodology for the acquisition of services, which is confirmed by the lack of standardization in the business practices associated with the services acquisition process. This results from the fact that the functional personnel currently managing the services programs are not considered members of the DoD acquisition workforce, and are typically not provided acquisition training under Defense Acquisition Workforce Improvement Act (DAWIA) requirements.

b.   Service Characteristics and Their Implications to Contracting

Intangibility of service outcomes makes it difficult to clearly describe and quantify services, and, therefore, to contract for services. Consider, for example, the difficulty in writing a contact for an educational service involving academic lectures. How does one define a "pound of education," and how can one be sure when the contract is fulfilled satisfactorily. As Karmarkar and Pitbladdo

(1993) explain, this is the reason why in such cases we do not contract around quantities at all; rather, we contract around process delivery. In general, the more information intensive the service is, the more difficult it is to develop clear and meaningful contracts.   This difficulty is somewhat reduced in services in which physical objects play a dominant role.

Intangibility of outputs also makes it *difficult to define and measure quality*. For example, even for a simple custodial service such as cleaning, it is not easy to define the desired level of cleanliness. The levels of cleaning needed for an office is certainly different than for a hospital operating room. The desired time duration for maintaining a clean status can also be an important matter in writing a contract for cleaning service. As research in service quality has found, customers typically evaluate the quality of service based on the outcome of a service as well as the customer's experience with the process of service delivery. For example, in a dining facility, not only must the food be tasty, but the manner in which the food is served must also be courteous, prompt and friendly. This means that the contracts for many services should not be based solely on outcomes but should include specifications on both the outcome and the customer's experience with the process.

Co-production requiring presence and participation of customers in the creation of many services is an important characteristic of services. For example, in an IT services such as software development, a customer's input in terms of desired specifications of a software system is critically important. For example, however competent the software developer may be, the developed software will not be satisfactory if the specifications do not accurately reflect the true needs of the customer. Hence, the contracts for services should ideally specify not only what the service provider should do but also what the customer should do. Otherwise, a satisfactory service outcome may not be realized.

Diversity of Services also makes it difficult and undesirable to use the same contract vehicles or procedures for different services. For example, given the differences in medical services versus custodial services, it is important that the contracts for these services are customized to suit the lifecycle needs of individual services.

Finally, services are complex and may involve multi-stage processes. This makes it important, yet challenging, to write contracts that are flexible enough to cover all relevant scenarios and eventualities. Moreover, if such contracts cannot be satisfactorily defined, it may be more desirable to deliver certain services using internal resources than to outsource them.

c.   Service Markets and Contracts

The above-discussed special features of services lead to significant differences in the process of production, sale and consumption of services. These, in turn, have implications for market structure, pricing, and contracting for services. While the operational implications of service characteristics have received some attention, there have been very few attempts to capture the implications for markets. The large majority of papers dealing with service competition have addressed issues like queues and congestion, and their consequences for customer waiting time.

While queuing is certainly an issue central to services—customers must access service systems because of the *lack of portability* of services—the difference relative to manufacturing is primarily one of degree. There are, on the other hand, several important characteristics of services which remain untreated in terms of market models. For example, there is little to be found on the subject of models with joint production. Similarly, the inability to measure and meter service output renders standard price-quantity mechanisms untenable. The result is that prices must be set on a case basis, by specific bilateral contracting based on inputs rather than outputs, or by repeated renegotiation and contracting. While these are not individually all new issues, there does not seem to be an integrated treatment of service markets from this viewpoint.
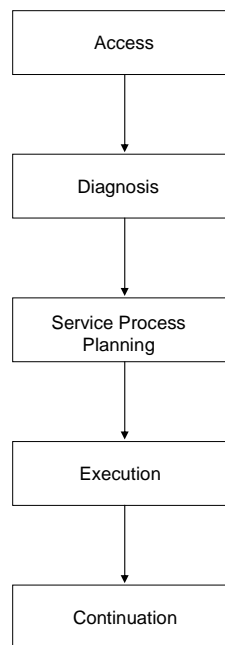
Karmarkar and Pitbladdo (1993) present some key features regarding service contracting that are relevant to the development of a service quality model. First and foremost, service operations are always post-contractual (with the possible exception of New York City automotive window washing). Fixed-price contracts centered on output specifications can fail on two accounts. First is the difficulty of conceiving or verifying meaningful output specifications, and second is the variability of customer inputs and joint production which makes fixed-price contracts risky for the firm even when the output specifications can be well defined. Alternatively, contracts based on process specifications, such as time and materials, can turn out to be unsuitable since these can be risky for customers. These dual risks for firms and for customers can be addressed via stage-wise or contingent contracting, in which the process is broken into stages, and the price for a given stage is made dependent on the outputs of previous stages. For example, there may be a fixed fee for a diagnosis, and a fixed fee for treatment which, however, depends on the outcome of the diagnosis. The uncertainty in customer inputs is resolved by the diagnosis before it materializes in terms of treatment cost.

d.   Stage-wise Decomposition of Services

The presence of a tangible, portable output which can be quantified by both vendor and buyer allows, perhaps forces, considerable simplification in the market-forming process of manufactured goods. Contracts for manufactured goods are centered around a clearly defined junction between production and use, at which point responsibility is transferred from producer to customer. While the value of a product to a customer may actually depend on the customer-specific uses to which the product is put, such information is not needed at the market interface, where customers can reveal their preferences through price-quantity negotiations. Similarly, specifications of the production process have no relevance at the market interface apart from their impact on the specifications of the product.

For services, the transaction between customer and provider must be represented in greater detail. Figure 1 shows the sequence of steps involved in a service transaction as seen by a customer. At the end of each step is the state that is reached, observed by either the buyer or the vendor of the service. Karmarkar and Pitbladdo discuss why, 1) contract terms for the next stage are typically contingent on the states reached in the previous stages, and 2) switching to competing providers is an option at the end of each stage. We hasten to note that not all services necessarily involve all these steps.

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Figure 1. A Conceptual Model of a Service Lifecycle

The first step is *access* to the service; this may involve bringing a customer to the service system, or the reverse. The second stage is *diagnosis.* For our purposes, diagnosis is defined as the mapping of customer requirements of a service into a technical or process specification. For example, a customer at a car repair facility may describe certain problems that he or she has experienced based on which repair needs can be assessed. The process of diagnosis identifies the underlying technical problem, perhaps as a syndrome (collection of symptoms) or perhaps in terms of the underlying mechanism. The medical analogy is obvious. Similarly, a client of a financial planning service may describe problems in terms of college payments and retirement. The planner may convert the statement to needed cash flows, risk attitudes and state preferences. Diagnosis is likely to be an interactive or joint process. In some cases, the diagnosis step is performed by the customer alone.

The third stage, *process planning,* is the generation of alternative service processes or treatments to meet the output requirements defined by the diagnosis. This may be a joint production process. In some cases, the alternatives available are already stated and fixed. A menu at a restaurant is an example. In others, processes or alternatives can be highly specialized to the customer's needs. It is conceptually useful to note that diagnosis, coupled with process planning, is the dynamic equivalent of Quality Function Deployment (QFD) (Hauser & Clausing, 1988). In manufacturing, QFD consists of mapping generic customer needs into clearly defined product specifications. Diagnosis and process-plan generation consist of mapping specific customer needs and desires into clearly defined process specifications, particular to the customer.

The fourth stage is the *execution* of the service process itself. Once again, this may or may not involve joint production. Finally we add a fifth stage, *continuation*, which represents the continuing consumption or consequences of service outputs (the provider's role in this stage can be characterized as long-term service support). The reason for this is that the outputs or consequences of many services (e.g., health care, financial planning, consulting) cannot be completely evaluated immediately. It is instructive to note here that, in the manufacturing case, the

counterpart of this fifth stage constitutes the entirety of the customer involvement with the product. The service provider may continue to have a role in this stage in the form of direct interaction and consultation or a set of instructions along the lines of a "user's manual." Surgery provides a clear example, involving a schedule of required and proscribed activities, along with follow-up checkups and telephone consultations.

In the next section, we build on some concepts discussed above to propose a program management approach for services acquisition.

Towards a Program Management Approach to Services Acquisition

This research on the acquisition of services will focus on the application of a program-management approach and project-management concepts to services acquisition. This section will first discuss some basic concepts of program management and then discuss how these concepts are currently being used in the acquisition of systems and products, specifically defense weapon systems. The next section will discuss the application of a program-management approach and project-management concepts to services acquisition.

a. An Overview of the Program Management Approach

Review of the current literature shows that the use of a well-defined, disciplined methodology and infrastructure for the management of complex projects is critical for a project's success in meeting cost, schedule, and performance objectives (PMI, 2004, Kerzner, 2006). We use the term "program management" to describe the approach and methodology needed for the management of complex projects. A program management approach includes the infrastructure that facilitates the successful attainment of cost, schedule, and performance objectives. A program management approach refers to the centralized, coordinated management of a group of projects to achieve the program's strategic objectives and benefits (PMI, 2004). In addition, programs themselves consist of related projects managed in a coordinated way to obtain benefits and control (PMI, 2004). Thus, a disciplined program management approach includes the following project management concepts: project lifecycle, integrated project processes, an assigned and dedicated project manager, empowered cross-functional project teams, and an appropriate project organizational structure. These project management concepts will be briefly discussed.

1. Project Lifecycle

An effective way of managing projects is to divide the project into phases to provide better management and control. These phases make up the project lifecycle. The phases of the project lifecycle can be used to manage and control the activities that are conducted within each project phase. By using the phases of the project lifecycle and establishing control gates or milestones between project phases, the project manager can control the progression of the project. Although project lifecycles are different for each specific type of project, many organizations will establish a standardized lifecycle for their projects. Typically, the project lifecycle of a system consist of the following phases: conceptual, planning, testing, implementation, and closure (Kerzner, 2006). Later in this report, we will discuss how the project lifecycle is used in defense weapon system projects. We will also discuss the development of a project lifecycle for service acquisition projects.

2. Integrated Processes

A disciplined program management approach includes the integration of various project management processes used throughout the project. These various project processes typically include such processes as requirements development, scheduling, cost management, quality management, risk management, and contracts management (PMI, 2004). Although each of these specific project processes reflects different functional areas, a disciplined program management methodology would integrate these various processes to ensure that each of these areas are coordinated and integrated within the total project effort. In addition to integrated processes, the PMI project management body of knowledge establishes five project management process groups. These project management process groups include initiating processes, planning processes, monitoring and controlling processes, and closing processes (PMI, 2004). Each of these project management process groups includes various functional processes that are part of that specific process group. For example, the planning-process group would include such processes as scope planning, quality planning, risk-management planning, procurement planning and solicitation planning. In order to effectively and successfully manage projects, these various functional processes need to be coordinated and integrated throughout the total project effort. Having integrated project processes are key to successful project management.

3. Project Teams

Just as integrated processes are an essential for effective project management, integrated project teams are also essential. A disciplined program management methodology includes the establishment of integrated project teams consisting of project team members representing each of the different functional areas that are part of the project effort. For example, a project team may include functional experts representing the various processes that are used in the project such as risk management, requirements management, and contracts management. These functional experts on the project team are responsible for providing their expertise in support of the project objective. Although the project team consists of these various functional experts, the activities of these project team members must be coordinated and integrated to ensure accomplishment of the project object. The coordination and integration responsibility belongs to the project manager.

4. Project Manager

A critical aspect of a disciplined project management methodology includes the assignment of a dedicated project manager to oversee the activities of the project. We have already stated that the project effort includes various functional processes conducted by functional experts on the project team. We also stated that there are project management process groups that are used to help integrate these various functional processes. The role of the project manager, therefore, is to coordinate and integrate the various project activities to ensure successful completion of the project (Kerzner, 2006). The project manager is responsible for ensuring that all members of the project team support the projects objectives. Thus, having a dedicated project manager, who is responsible for managing the project activities and ensuring the achievement of the project objectives, is an essential part of a disciplined project management methodology.

5. Organizational Structure

An appropriate organizational structure is also an essential element of a disciplined project management methodology. An organizational structure that supports the integrated project management processes, integrated project teams, and the roles and responsibilities of the project manager will significantly contribute to the success of the project. One of the three main types of organizational structures—functional, matrix, and pure project—is typically used in organizations that perform projects (PMI, 2004). The degree of project manager authority, resource availability and budget control will be affected by the type of organizational structure (PMI, 2004). Some of the factors to consider in selecting the appropriate type of organizational structure include: the number of functional areas involved in the project, the level of integration needed within the functional areas and between the organization and the customer, the nature of the technology used in the project work, and the organization's previous experience in performing the work required by the project.

b.   Application of Program Management Concepts to Weapon Systems Acquisition

The previous section discussed the basic project management concepts such as the project lifecycle, integrated processes, project teams, project manager, and organizational structure. These program management concepts are well established in the Department of Defense weapon systems acquisition environment. In fact, many of today's modern project management tools and techniques were developed during the Cold War. Weapon system programs such as the land-based ICBM and sea-based ballistic missile programs became the proving grounds for some of today's modern program management processes (Kerzner, 2006). In today's DoD weapon systems acquisition environment, program management concepts continue to be integral to the successful management of these critical and high-technology projects.

The *Department of Defense Directive 5000.1* establishes the defense acquisition system as the management process by which the DoD provides effective, affordable, and timely systems to the users (DoD, 2003). This directive establishes the role of the program manager as the designated individual authorized and responsible for accomplishing the program objectives. The program manager is the designated individual that is accountable for costs schedule and performance reporting to the milestone decision authority (MDA) (DoD, 2003).

The *Department of Defense Instruction 5000.2* establishes the defense acquisition management framework as the project lifecycle for major defense acquisition programs (USD(AT&L), 2003, May 12). This lifecycle consists of the various phases, decision points, and project review points that are part of the project lifecycle. See Figure 2 for an illustration of the DoD Acquisition Management Framework.
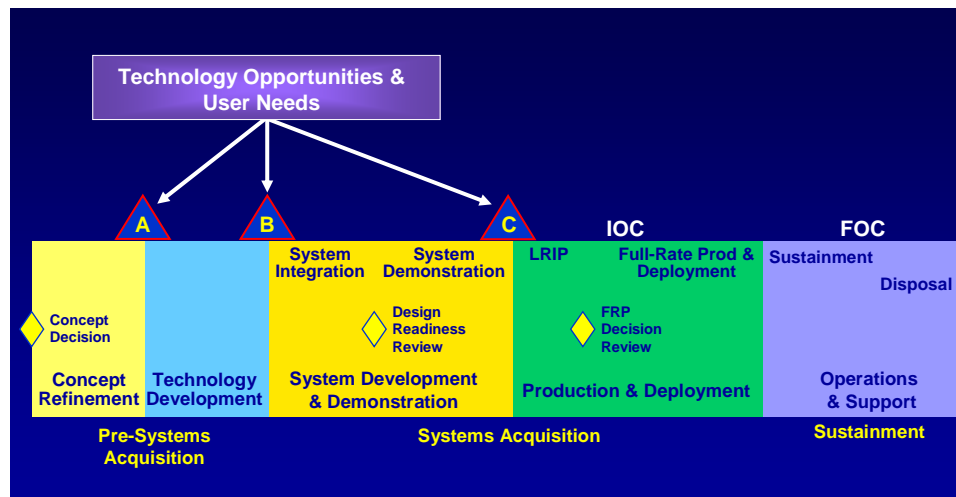
Figure 2. The Defense Acquisition Management Framework

In addition, the *DoD 5000* regulations also established the use of integrated product teams (IPTs) and integrated processes throughout the weapon systems acquisition management lifecycle. Through the use of effective collaboration, program managers are responsible for making project decisions and leading project execution by maintaining continuous and effective communication through use of integrated project processes.

Finally, for weapon systems acquisition management, the DoD relies heavily on unique organizational structures such as the matrix organizational structure and, in some instances, project-type structures for the management of defense acquisition programs. Figure 3 is an example of an organizational structure for a weapon system acquisition program.
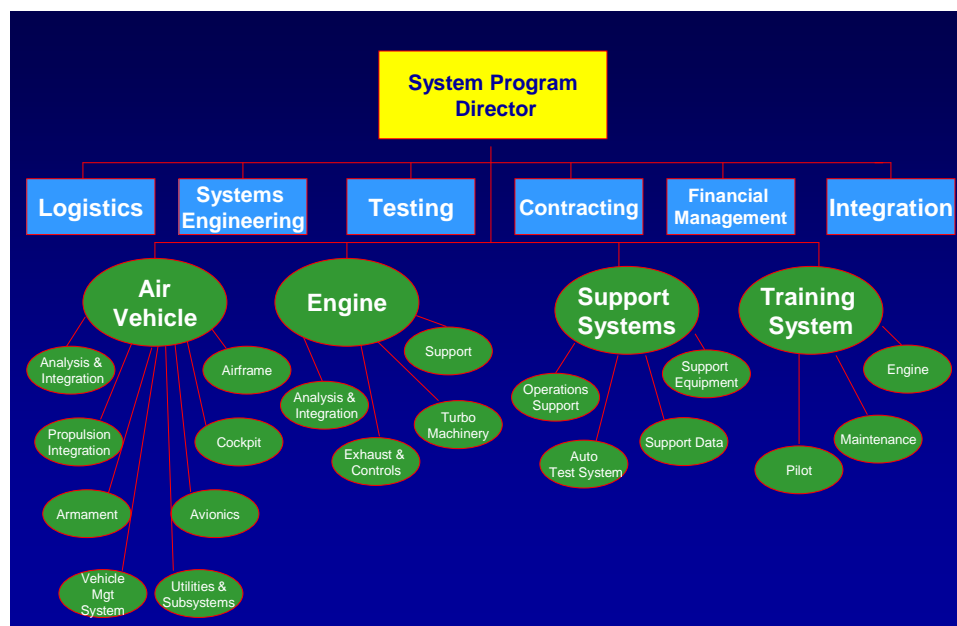
Figure 3. Organization Structure of a Weapon System Acquisition Program

Thus, the basic concepts reflective of a program management approach are well established in DoD weapon systems acquisition management. The use of project lifecycles and control gates, integrated processes, established project manager and project teams, and an effective organizational structure have been successfully used in this specific sector of the Department of Defense. The next section of this research will discuss how this program management approach (consisting of these basic project management concepts) can be used by the DoD in the acquisition of services.

Applications of Program Management Concepts to Services Acquisition

Our previous discussion focused on the use of a program management approach and its related project management concepts found in the current literature. These project management concepts included the use of a project lifecycle and control gates, integrated processes, a dedicated program manager and integrated project teams, and an organizational structure conducive to the integration of project activities. We also discussed how this program management approach and these project management concepts have been well established in the weapon systems acquisition management environment. We identified Department of Defense directives and instructions that support, even mandate the use of some of these project management concepts. This section will now focus on the acquisition of services within the Department of Defense. We will look at the acquisition of services at the installation level, command level, and service level. The purpose here is to illustrate how a program management approach and project management concepts can be effectively applied at each of these levels to successfully manage service acquisition programs.

In exploring DoD services acquisition, our research included basic installation-level types of services that are commonly acquired in support of the installation mission. The installations researched included Travis Air Force Base California, Randolph Air Force Base Texas, Presidio of Monterey California, and the Naval Postgraduate School, California. At the installations visited, personnel were interviewed for this research; we determined that although some project management concepts were applied, they were not applied in a consistent manner, or were not institutionalized throughout the organization. In addition, at many of these locations, although project management tools and concepts were being applied, this utilization did not necessarily result in a program management approach to acquiring services.

Typically, at the installation level, the acquisition of services is managed using more of an ad hoc approach as opposed to a program management approach.

1. Project Lifecycle

In terms of using a project lifecycle, our research indicated that the contracting process was typically used as the project lifecycle. Although the contracting process is an integral part of the acquisition lifecycle for DoD weapon systems acquisition, the project lifecycle is separate from the contracting process lifecycle.

2. Integrated Processes

In addition, our research indicated that although various project management processes were used at the installation level, these processes were not necessarily integrated in the management of the services contracts. Although we did find the various project management

processes (such as contracting process, risk-management process, quality-assurance process, and contract-funding process), we did not see the integration of these processes.

3. Project Teams

Furthermore, the use of informal project teams was in existence at these installation-level organizations. Although these project teams were in existence, the structures of these project teams were created more on an ad hoc basis than established as formal project teams.

4. Project Manager

Closely related to the above was the ad hoc approach to the establishment of a project manager for services acquisition. In many cases, the project manager, or program manager, as sometimes called, existed at the major command headquarters level as opposed to the installation level. As we will discuss in the next section on Major Command level management of services acquisition, we found that many service acquisitions were centrally planned at the headquarters and then de-centrally executed at the installation level. If there is an assigned program manager, that individual is typically assigned at the Major Command level, with oversight responsibility for the installation-level activity. In these instances, although the program manager was located at the headquarters level, there was no program manager at the installation level. In this case, although the quality assurance evaluators (QAE) represented the program manager, the QAE does not perform program management responsibilities. In addition, the contracting officer at the installation typically functioned as the de-facto program manager due to the lack of any program manager at the site. It should be noted that the procuring contracting officer (PCO) at the Major Command headquarters where the services acquisition was centrally planned and executed delegated the contract to the administrative contracting officer at the installation where the contract was administered. Thus, the PCO, responsible for proving contracting support for the centrally planned and executed services acquisition, would delegate the administration tasks to the ACO for the decentralized administration of the services contract. However, the program manager retained the program management functions of the services acquisition.

5. Organizational Structure

Finally, in terms of organizational structures, at the installation level our research did not identify any specific or unique organizational structures specifically established for the acquisition of services. The installations we researched reflected the traditional organizational structures and organizational mission of the Defense Department. We did not see any projectized or matrix organizational structures used in the management of services contracts at the installation level.

Preliminary Conclusions

Our preliminary conclusion in this ongoing exploratory research has identified some unique aspects of services and how they affect the services acquisition process. We developed a conceptual model of a service lifecycle that can be used in analyzing the DoD's services acquisition process. We also discussed the program management approach and identified basic project management concepts and discussed how these concepts are being used in the acquisition of defense weapon systems. Our current research has observed that the program management approach is applicable to the acquisition of services within the DoD. We have also initially concluded that the basic project management concepts (such as project lifecycle,

integrated processes, project team, project manager, and organizational structure) can be applied to the acquisition of services. Our currents research leads us to believe that the application of a program management approach and the adoption of basic project management concepts to the acquisition of services will improve the management and oversight of these services contracts. Our further research will explore in more detail how this program management approach and project management concepts can be used to improve the DoD's services acquisition management.

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Panel 20 - Military Logistics and Maintenance: Beyond Lean and Six Sigma

Thursday, May 17, 2007
 	
3:30 p.m. – 5:00 p.m.
	Panel 20 - Military Logistics and Maintenance: Beyond Lean and Six Sigma
	
	Chair:
	
	    Garry B. Richey, Executive Director, Oklahoma City Air Logistics Center, Tinker Air Force Base
	
	Discussant:
	
	    Dale L. Moore, Deputy Corporate Deployment Champion NAVAIR AIRSpeed.
	
	Papers:
	
	Lean Six Sigma Implementation for Military Logistics to Improve Readiness: Enterprise Challenges Facing the Strategic Sourcing of Services
	
	    Keebom Kang and **Uday Apte**, Naval Postgraduate School
	
	Beyond AirSpeed: How Organizational Modeling and Simulation Further Reduced Engine Maintenance Time
	
	    Lt. Col. Joel J. Hagan, USAF, **Capt. William G. Slack**, USMC, **Roxanne Zolin** and **John Dillard**, Naval Postgraduate School

Chair: Garry B. Richey, Executive Director, Oklahoma City Air Logistics Center, Tinker Air Force Base, was selected for reassignment as Director, Logistics, Installations and Mission Support, Headquarters Air Education and Training Command, Randolph Air Force Base, Texas.

Garry B. Richey, a member of the Senior Executive Service, is Executive Director, Oklahoma City Air Logistics Center, Tinker Air Force Base, Okla. He is responsible for assisting the commander in providing worldwide logistics support for assigned Air Force weapon systems, including the C/KC-135, E-3, B-1B, B-52 and the B-2 stealth bomber.

Mr. Richey was born in Chickasha, Okla., and graduated from Duncan (Okla.) High School. He was drafted into the U.S. Army in 1972 and served at Fort Benning, Ga., until he was discharged in 1974. In 1977, he received a bachelor's degree in speech communication from the University of Oklahoma and started his civil service career as a logistics management specialist at Tinker AFB, Okla. His career includes acquisition and logistics experience as a director and logistics manager in propulsion, aircraft and item management. Mr. Richey also served as the Proposal Manager for the Tinker AFB bid in the Kelly AFB Propulsion Business Area public-private competition, which was awarded to Tinker AFB in February 1999.

Prior to his current position, Mr. Richey was the Deputy Director of Logistics, Headquarters Air Mobility Command, Scott AFB, Ill. He was responsible for providing policy and guidance to organize, train and equip aircraft maintenance, transportation, supply, contracting, and logistics plans units at 14 major active air installations in the United States, and 17 en route locations around the world. He also assisted in the

readiness of more than 616 aircraft and 80,339 people in the Air Force Reserve and Air National Guard, providing total force augmentation to support flexible, global reach for America.

Discussant: Dale L. Moore has served as the NAVAIR AIRSpeed Deputy Corporate Deployment Champion in support of RDML Mark Skinner, the NAE AIRSpeed Deployment Champion since May 2004. NAVAIR AIRSpeed supports the command's deployment of continuous process improvement and productivity-related strategies, tools, and methodologies, including Lean, Six Sigma, and Theory of Constraints. NAVAIR AIRSpeed deployment is designed to drive process efficiencies and embed a culture of productivity throughout an enterprise of more than 37,000 military, civilian, and contractor support personnel. Moore leads the Naval Aviation Enterprise AIRSpeed Merge Governance Team to develop the organizational governance construct for deploying and executing AIRSpeed across the 180,000 person NAE work force.

Moore is a trained George Group Lean Six Sigma Black Belt and holds a master's degree in product development (with distinction) from the Navy Postgraduate School with certificates of completion from the M.I.T. Sloan School of Management and the M.I.T. School of Engineering, a bachelor's degree in mechanical engineering from the University of Delaware, and is a graduate of the Defense Systems Management College's 20 week Program Managers Course where he has lectured for more than 12 years on "Aerospace Materials in Acquisition" and "Advanced Manufacturing."

Lean Six Sigma Implementation for Military Logistics to Improve Readiness

Presenter: Keebom Kang, Associate Professor, joined the Naval Postgraduate School in 1988, where he teaches supply-chain, logistics engineering and computer simulation modeling courses for the MBA program. His research interests are in the areas of logistics and simulation modeling in various military applications. He received his PhD in Industrial Engineering from Purdue University. Prior to joining NPS, he was on the faculty of the Industrial Engineering Department at the University of Miami, Coral Gables, Florida (1983-1988). He had held visiting professor positions at Syracuse University (Summer, 1985), Georgia Institute of Technology (Fall, 2003), Asia Institute of Technology in Thailand (Winter, 2004), and Pohang Institute of Science and Technology in Korea (Spring, 2004).

Dr. Kang has published many theoretical and applied papers in *Operations Research, IEEE Transactions in Communications, IIE Transactions, Telecommunication Management, Naval Logistics Research*, and other technical journals and conference proceedings. He was the Co-editor of the *1995 Winter Simulation Conference Proceedings* and the program chair for the 2000 Winter Simulation Conference. He served as an editorial board member for *IIE Transactions,* an associate editor for *IMA Journal of Mathematics for Management Science*, an associate editor for *IIE Transactions Special Issue on Computer Simulation*, and as a referee for many professional journals, including *Operations Research, Management Science*, and *Naval Logistics Research*. He also served as a proposal-review panel member for the National Science Foundation (1990, 1992, 1994). He is currently an Associate Editor for the *Naval Research Logistics* (2006-present).

Presenter: Uday Apte, is Professor of Operations Management at the Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA. Before joining NPS, Dr. Apte taught at the Wharton School, University of Pennsylvania, Philadelphia, and at the Cox School of Business, Southern Methodist University, Dallas. He is experienced in teaching a range of operations management and management science courses in the Executive and Full-time MBA programs.

Dr. Apte has served as a founder and President of the College of Service Operations, Production and Operations Management Society (POMS), as a board member of POMS, and as guest editor of *Production and Operations Management* journal. Areas of his research interests include managing service operations, supply-chain management, technology management, and globalization of information-intensive services. He has published over 30 articles, five of which have won awards from professional societies. His research articles have been published in prestigious journals including *Management Science, Interfaces, Production and Operations Management, Journal of Operations Management, Decision Sciences, IIE Transactions, Interfaces,* and *MIS Quarterly.* He has co-authored two books, *Manufacturing Automation* and, *Managing in the Information Economy*.

Dr. Apte holds a PhD in Decision Sciences from the Wharton School, University of Pennsylvania. His earlier academic background includes a MBA from the Asian Institute of Management, Manila, Philippines, and Bachelor of Technology (Chemical Engineering) from the Indian Institute of Technology, Bombay, India.Naval Postgraduate School.

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Abstract

In general, during the lifecycle of a weapon system, a significantly larger amount of money gets spent on operating and maintaining the system than on acquiring it. Hence, efficient logistics systems, including transportation, inventory management, modifications and maintenance activities, are critically important for containing the lifecycle costs of weapon systems and for maintaining the highest level of military readiness given the extant fiscal constraints. This paper describes Lean Six Sigma (LSS), a strategically important and proven logistics initiative for both reduced lifecycle costs and improved readiness.

With aging weapon systems, the US Department of Defense is facing ever-increasing military expenses to maintain military readiness. Hence, the Department of Defense is keenly interested in implementing Lean Six Sigma in all the services. We begin this paper by providing an overview of military logistics and discussing the critical concepts of readiness and cycle-time. Thereafter, we present an overview of Lean Six Sigma methodologies—including Lean production and Six Sigma, and describe the experience in implementing Lean Six Sigma in the Army, Navy and Air force. The paper ends with a discussion of the managerial guidelines for successfully implementing Lean Six Sigma.

Keywords: Lean Six Sigma, Lean Production, Six Sigma, Military Logistics, Readiness, Lifecycle Costs

Introduction

Three essential factors to maintaining strong military power and readiness are well-trained troops/ well-educated officers, reliable high-tech weapon systems, and well-designed logistics systems to support troops and improve the readiness of the weapon systems. In purchasing weapon systems, program managers widely use acquisition costs as the primary, and at times the only, criteria for decision-making. However, in general, during the lifecycle of a weapon system, a significantly larger amount of money gets spent on operating and maintaining the system than on acquiring it. Hence, efficient logistics systems—including transportation, inventory management, modifications and maintenance activities—are critically important for containing the lifecycle costs (LCC) of weapon systems and for maintaining the highest level of military readiness given the extant fiscal constraints. This paper will describe Lean Six Sigma (LSS), a strategically important and proven logistics initiative for both reduced lifecycle costs and improved readiness.

Two major components of LCC are *Acquisition* costs and *Operations and Maintenance* (O&M) costs. Acquisition costs include such items as research, development, test and evaluation, program management, engineering design, initial spare parts, manufacturing and production, facilities and construction, and initial training. O&M costs, on the other hand, include such cost categories as labor, materials, and overhead, operations, scheduled and unscheduled maintenance, training, replacement and renewal, transportation,

system/equipment modification, technical data collection, documentation and database management, energy and facility usage, and disposal costs. Without question, the logistics systems have a great deal of influence on the size of O&M costs.

It is difficult to generalize the percentage of money spent on operations and maintenance of a typical weapon system. Some literature points out that the O&M costs contribute to 60% of the total lifecycle cost on average (DAU, 2006), while other sources estimate these costs to be as high as 80% of the total (Cost Analysis Improvement Group, 1992). In any event, with the Service Extension Program (SEP) that many weapon systems are experiencing these days, the percentage of the total lifecycle cost spent on O&M is simply becoming larger. Most weapon systems were originally designed for a lifecycle of 20+ years, but some have been stretched to last as long as 50 years. In the case of B-52 aircraft, for example, the lifecycle is expected to extend to 80 years, in which case the O&M costs expect to form as much as 90% of its lifecycle cost (Parker, 1999).

With aging weapon systems, the US Department of Defense (DoD) is facing ever-increasing O&M costs. The DoD is, therefore, keenly interested in applying Lean Six Sigma methodologies to cut down O&M costs. Experiences of the private sector in implementing Lean Six Sigma illustrate that the methodology is as effective in improving business processes as it is in improving the manufacturing processes. Thus, successful implementation of LSS methodologies would also reduce acquisition costs by improving acquisition and contracting processes. Hence, in this paper we will discuss Lean Six Sigma and its application in the military. This paper is organized as follows: in Section 2, we provide an overview of military logistics and discuss the critical concepts of readiness and cycle-time. In Section 3, we describe background material for LSS methodologies. Section 4 includes examples of LSS implementation in the US Army, the US Navy and the US Air Force. In Section 5, we conclude the paper by presenting managerial guidelines and by discussing the challenges present in implementing LSS in the military.

Military Logistics

Military Logistics support deals with *everything* required to provide warfighters with the *right stuff* at the *right time* at the *right place* at the *right cost.* The goal of military logistics support is to maintain the highest possible level of readiness, commonly expressed as operational availability: $Ao = \dfrac{MTBM}{MTMB + MDT} = \dfrac{uptime}{uptime + downtime}$, where MTBM is the mean time between maintenance, and MDT is the maintenance down time—which includes repair time and administrative and logistics delay times. Intuitively, operational availability is the fraction of time a weapon system is operational or mission capable. Clearly, operational availability can be improved by increasing MTBM (i.e., increasing reliability) and/or decreasing MDT (i.e., reducing repair or cycle-time). Thus, the two key issues to improve weapon systems readiness are reliability improvement and cycle-time reduction.

From Little's Law (Little, 1961), reducing repair or cycle-time reduces pipeline inventory directly, and leads to significant savings in inventory costs. The relationship between repair or cycle-time and inventory levels is critically important (yet, troublesome) in the military because it crosses physical, organizational, and financial barriers. Inventory managers strive to consolidate and minimize stocks of piece-parts to free-up resources for other priorities. They also seek to get quick turnaround on repairable components in order to minimize pipeline inventory. However, stockout of spare parts or consumable components results in delays in

repair processes and, eventually, serious readiness degradation. Cycle-time reduction in a military logistics channel (repair depots, intermediate-level maintenance, inventory control points, and supply centers) also means that more weapon systems are available in the field or fleet. On the other hand, increased cycle-time causes a vicious cycle of deteriorating military readiness. For instance, poor logistics support (e.g., lack of spare parts, personnel, and/or training) increases the cycle-time, which in turn decreases readiness, *Ao*. Therefore, the warfighters are forced to satisfy mission requirements with a fewer number of mission-capable weapon systems, resulting in stress on those fewer mission-capable systems. Due to this stress, more system failures occur, which in turn generate more workload at repair facilities. Thus, the repair turnaround time can become even longer. And the vicious cycle can go on.

The following simple example explains the importance of cycle-time reduction in military logistics. Suppose that the US Navy has 800 F/A-18 Hornet aircraft, each of which costs $50 million, and that the Standard Depot Level Maintenance (SDLM) is done every 4 years. If the MDT is one year, the readiness, *Ao,* will be 4/(4+1) = 0.8. Thus, only 80% of 800, or 640, aircraft will be mission-capable on average since an aircraft would be available for mission for four years (and at the depot for one year) out of every five years. This also means 160 aircraft will be non-mission capable at any given time. If the MDT can be reduced to 6 months, *Ao* will be 0.889; or, only 89 instead of 160 aircraft will be at the depot for maintenance at any given time. It is equivalent of having 71 additional aircraft (worth more than $3.5 billion) in the fleet. On the other hand, if having 640 mission-capable aircraft available is adequate, it would mean reducing the fleet size by 80 aircraft and freeing up $4 billion expenditure for other purposes. See Kang, Gue and Eaton (1998) for a cycle-time reduction case study at a Navy depot.

The Department of Defense and its services have many on-going initiatives to cut down maintenance cycle-time to improve military readiness. The Navy has been working on the *Sea Based Logistic*s to cut down distribution time by supporting "customers" on shore directly from the sea by eliminating "Iron Mountains" (middlemen) in the supply-chain management context. Likewise, since 1995, the US Army has implemented *Velocity Management* (Dumond et al., 2001) which focuses on improving the speed and accuracy with which materials and information flow from factories to fox holes. The US Air Force has implemented *Agile Logistics,* and the US Marine Corps, *Precision Logistics* for cycle-time reduction.

More recently, all branches of the US military, Army, Navy and the Air Force, are actively applying *Lean Six Sigma* methodology to their various activities to reduce cycle-time and to reduce maintenance expenses. We will describe the details of current initiatives of Lean Six Sigma in the military services in Section 4.

Levels of Maintenance

We can use the US Navy's aviation maintenance system to understand how military maintenance logistics are typically conducted. The Naval Aviation Maintenance Program divides maintenance into three levels: organizational level (O-level), intermediate level (I-level), and depot level (D-level), which are similar in structure to multi-echelon logistics support systems of commercial firms (e.g., Blanchard, 2004) or other services. To achieve economies of scale in maintenance equipment and personnel, levels of maintenance are made progressively more capable, with D-level being the most capable. However, the longer turnaround time at D-level also increases the work-in-process and requires more spare parts to maintain the desired readiness level.

O-level maintenance is performed at the site and typically involves simple repairs or the replacement of modular components. I-level maintenance involves more difficult repairs and

maintenance, including the repair and testing of modules that have failed at the O-level. I-level maintenance for Navy aircraft is done at Aircraft Intermediate Maintenance Departments (AIMDs) ashore in naval air stations or afloat in aircraft carriers. D-level maintenance activities, called Naval Aviation Depots (NADEPs), ensure the continued flight integrity and safety of airframes and related flight systems throughout their service lives. This involves performing maintenance beyond the capabilities of the lower levels, usually on equipment requiring major overhaul or rebuilding of end-items, subassemblies, and parts. The Navy operates three NADEPs in the US (North Island, CA; Cherry Point, NC; and Jacksonville, FL) and fleet repair facility sites in Italy and Japan.

The repair cycle begins when an unserviceable repairable is turned for maintenance, and it ends when the item is recorded on the inventory control point records as being ready-for-issue (RFI). Repair cycle-time includes shipping and processing time, accumulation time, repair time, time awaiting parts, and delivery time. Unserviceable items may remain in storage for extended times for various reasons.

Readiness and Inventory Management

Aviation readiness is measured by computing fully mission-capable (FMC) rates. The FMC rate indicates the operational availability of the aircraft in a unit—that is, the fraction of aircraft that are mission capable at any arbitrary time. When aircraft are partially mission capable or not mission capable, it is because of either maintenance or supply problems.

Aviation items, especially repairables, are very expensive to maintain. For example, each aircraft carrier carries onboard an Aviation Consolidated Allowance List (AVCAL) consisting of consumable and repairable items and subassemblies required to support the Air Wing for 90 days of wartime operations. A typical AVCAL consists of tens of millions of line items valued at hundreds of millions of dollars. Repairable items represent only 10% of the total line items, but 90% of the total value of the AVCAL (USS Independence Shipboard Uniform Automatic Data Processing System Report 008, 1991, July 26).

Material readiness demands spare parts, but fiscal constraints have put pressure on the Navy to reduce inventory levels at AIMDs and stock points. The two-part solution is easier said than done: select a "better" mix of spares and reduce repair cycle-time. Both tend to improve readiness for a given cost or achieve the same readiness for lower cost.

The relationship between spares/inventory levels and cycle-time is a key to understanding how to achieve higher readiness at lower cost. Kang (1993) shows the diminishing marginal utility of spare parts, implying that additional spare parts beyond a certain threshold level will not improve readiness. Those additional spare parts, once they are turned in after failure, will simply increase the work-in-process or inventory at repair facilities. Spares levels and repair cycle-time must be considered together when attempting to improve material readiness (see Kang & Gue, 1997).

During the past 30 years, the military has been implementing spares methodologies based on the readiness-based METRIC models such as those described in Sherbrooke (1992). Rather than the traditional approach to inventory problems that minimize holding and ordering costs for individual items subject to a service level, readiness-based models seek to maximize *Ao* for multiple items directly and simultaneously, subject to a budget constraint. It is possible to measure *Ao* for a specific component, such as an aircraft engine, as opposed to measuring *Ao* for the aircraft itself. An improvement in *Ao* for the engine will provide some marginal improvement in Ao for the aircraft. But this improvement will not be one-to-one: large

improvements in engine availability may yield only trivial improvements in aircraft availability, depending not only on the failure rate of the engines, but on the performance and availability of all the other critical components of the aircraft. The readiness-based models are important to military systems because they treat all of the critical components in a weapon system together in order to achieve the singular objective of maximizing the *Ao* of the weapon system. Implementation of these models requires detailed, accurate information about the reliability of components, but the rewards have been worth the effort in many systems. For example, Sherbrooke (1992) reports inventory investment being cut nearly in half, with no degradation in readiness, during a test for the Air Force. Hale (1994) also shows significant inventory savings in the Navy after implementing readiness-based models.

Lean Six Sigma

Penchant for process improvement is inherent in human nature; even our distant ancestors discovered a better way to start fire, make arrowheads and spears, or build shelters (Dershin, 2004). Early improvements probably came about through trial and error and took hundreds (if not thousands) of years to become part of the human skill set. Almost up to the modern times, such improvements were the carefully guarded secrets of the select few. However, the fast pace of modern commercial/industrial economy has given rise to the structured problem-solving methodologies for process improvement that are well understood by and available to all.

Two major approaches for structured problem solving emerged separately in the 20th century and have come to be known as "Lean" and "Six Sigma" methodologies. Lean improvements focus on process speed and waste removal, while Six Sigma, like its predecessor Total Quality Management (TQM), focuses on the removal of process defects and the reduction of process variability. Ironically, Six Sigma and Lean have often been regarded as rival initiatives. Lean enthusiasts note that Six Sigma pays little attention to anything related to speed and flow, while Six Sigma supporters point out that Lean fails to address key concepts like customer needs and process variation. To some extent, these are valid arguments. Yet, they have been more often used by the practitioners to promote the choice of one versus the other approach. However, today's need for an even higher level of competitiveness than that achieved through implementing either methodology has now convinced practitioners that these two approaches are synergistic, and there is benefit to be realized by blending the two. Therefore, in the new millennium, we are witnessing the emergence of Lean Six Sigma (George, 2002; Nash, Poling & Ward, 2006).

Lean and Six Sigma are two different bodies of knowledge. The Six Sigma is all about locating and eliminating root causes of process problems. The Six Sigma tools, such as the "the five whys," are designed to find the root cause/s of the problems and build models of cause and effect. The process is then redesigned with the root cause/s eliminated.

Lean is different. As popularized by Womack and Jones (2003), the Lean roadmap is one of successive refinements to improve the overall process through the following steps (Apte & Goh, 2004):

- Specify value in the eyes of the customer
- Identify the value stream and eliminate waste
- Make value flow at the pull of the customer

- Involve and empower employees

- Continuously improve in the pursuit of perfection.

Since Lean Six Sigma is a synergistic blending of Lean Production and Six Sigma methodologies, we will present a brief overview of these two methodologies.

Lean Production

Lean can be defined as a set of principles and tools that helps us eliminate process activities that don't add value, and create "flow" in a process (Dennis, 2002). A Lean process is defined as one that uses only the absolute minimum of resources to add value to the service or product. Lean manufacturing can also be viewed as a management philosophy focusing on reduction of the eight types of wastes (Human Talent, Over-production, Waiting time, Transportation, Processing, Inventory, Motion and Scrap) in manufacturing or service processes ("Lean Manufacturing," 2006). By eliminating waste (muda), quality is improved, production time is reduced, and cost is reduced. Lean "tools" include continuous process improvement (kaizen), "pull" production process (by means of kanban) and mistake-proofing (poka-yoke). Lean, as a management philosophy, is also very focused on creating a better workplace through the Toyota principle of "respect for humanity."

Origins of Lean Production can be traced to the Scientific Management principles of Frederic Taylor (1911) and to the practical genius of Henry Ford (Levinson, 2002). But the principles of Lean Production were more fully embodied in its recent incarnations: Just in Time Systems and Toyota Production System (Ohno, 1988). The term Lean Production was coined by Womack, Jones and Roos (1991) in their best seller, *The Machine that Changed the World*. The book chronicles the transitions of automobile manufacturing from craft production to mass production to lean production. "Theory of Constraints (TOC)" popularized by Goldratt and Cox (1992) in their novel *The Goal* is also typically used in implementing Lean production. Simply put, TOC involves identification and use of the bottleneck (i.e., the constraint) of the system to set the operational pace of the system's components and to achieve a synchronous flow so as to maximize the throughput (i.e., the money-making potential) of the system.

At the heart of Lean is the determination of value. Value is defined as form, feature or function for which a customer is willing to pay. The processes that do not add value are deemed waste. The Lean framework is used as a tool to focus resources and energies on producing the value-added features while identifying and eliminating non-value added activities. Processes in Lean are thought of as value streams. Lead-time reduction and the flow of the value streams are the major areas of focus in Lean. *Value-stream mapping* helps teams understand the flow of material and information in creating and delivering the product or services being offered to the customer by the organization.

In summary, in its current implementation, the Lean methodology:

- Provides tools for analyzing process flow and delay times at each activity in a process,

- Emphasizes *Value-stream Mapping,* which centers on the separation of "value-added" from "non-value-added" work with tools to eliminate the root causes of non-valued activities and their cost,

- Uses Theory of Constraints as its integral element to identify bottlenecks and achieve a synchronous flow in the system,

- Recognizes and attempts to eliminate 8 types of waste/non-value-added work: defects, inventory, over-production, waiting time, motion, transportation, processing, and human talent, and

- Creates workplace organization through *Five S* methodology consisting of sort, straighten, sustain, sweep, and standardize.

Six Sigma

Six Sigma is a management technique that aims to develop and deliver near-perfect products and services. The primary goal of Six Sigma is to improve customer satisfaction (and, thereby, profitability) by reducing and eliminating defects. In this case, the defects may be related to any aspect of customer satisfaction: product quality, delivery performance, and product cost. Six Sigma is targeted at reducing variation in a business processes. It can also be a great way to permeate the culture of continuous improvement in an organization.

The term "Six Sigma" refers to a statistical construct that measures how far a given process deviates from perfection. A level of Six Sigma (about 3.4 defects per every million items) represents the highest level of quality: virtually all products and business processes are defect-free. It should be noted that most companies today function at only a three or four sigma level and lose 10-15% of their total revenue due to defects. Thus, a typical company stands to benefit significantly from implementing Six Sigma.

Six Sigma originated in 1986 with the efforts of Bill Smith, a senior engineer and scientist at Motorola (McCarty, 2004). It was originally used to improve manufacturing processes at Motorola. While Six Sigma has its roots in the total quality management (TQM) approach of the 1980s, today it is much more than that. It is now being used across a wide range of industries, including banking, insurance, telecommunications, construction, healthcare, and software. Interestingly, the methodology gained industry-wide acceptance in the mid-90s when Jack Welch, CEO of GE, successfully launched it within the entire company (General Electric, 2006) and began vouching for the billion-dollar benefits realized by GE through the use of Six Sigma methodology. For instance, in 1999 alone, GE reported that it saved $2 billion using Six Sigma principles.

In Six Sigma applications in service-sector industries, the program implies going beyond the highest quality level targeted in the manufacturing process. For example, an average of 3.4 errors in every one million financial transactions would not be acceptable to a financial institution. Six Sigma now has much broader meaning. Simply put, Six Sigma:

- Emphasizes the need to recognize opportunities and eliminate defects as defined by customers,

- Recognizes that process variation hinders our ability to reliably deliver high-quality services,

- Requires data-driven decisions and incorporates a comprehensive set of quality tools under a powerful framework for effective problem solving, and

- Provides a highly prescriptive cultural infrastructure effective in obtaining sustainable results.

In any improvement project, utilization of a well-defined improvement procedure is critically important. The most commonly used standard improvement procedure in Six Sigma is DMAIC (Define, Measure, Analyze, Improve and Control). DMAIC is a structured, disciplined, rigorous approach to process improvement consisting of the five phases, in which each phase is linked

logically to the previous phase as well as to the next phase. A detailed description of these phases can be found in Stamatis (2004) and Rath and Strong (2006).

In terms of the tools and techniques used for process improvement, there is only a marginal difference between Six Sigma and the Total Quality Management approaches. But what sets Six Sigma apart from TQM, which is perhaps the most important reason behind the success of Six Sigma, is the establishment of organizational infrastructure for ensuring continuous process improvement. Thus, Six Sigma should be ideally viewed as a management system that integrates strategic objective and measurement systems development, and provides the guidance for project prioritization and governance. It is a performance-management system to drive a more focused execution of the overall business strategy. The essential premise of the Six Sigma Management System is that there is a leadership team in place whose members are willing and capable of engaging in a disciplined, team-based process of continuously monitoring real-time organizational performance metrics and then taking action in the form of project reviews. The team engages in frequent dialogue regarding performance related to customer and market requirements as well as performance related to critical improvement projects. As a result of these efforts, an organization-wide dialogue is created that drives top-to-bottom focus on daily execution and a culture of continuous improvement.

Six Sigma identifies five key organizational roles for its successful implementation ("Six Sigma," 2006):

- *Executive Leadership* includes CEO and other key top management team members. They are responsible for establishing a vision for Six Sigma implementation.

- *Champions* are responsible for the Six Sigma implementation across the organization in an integrated manner.

- *Master Black Belts*, identified by Champions, act as in-house, full-time, expert coaches for the organization on Six Sigma initiatives.

- *Black Belts* operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.

- *Green Belts* are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving the overall results.

Please note that there exists a large variation in the way the above roles are defined and utilized within the Six Sigma implementations in different enterprises and that specific training programs are available to train people to fulfill these roles.

Lean Six Sigma

As noted earlier, the process improvement methods of Lean and Six Sigma have been practiced separately for many years. However, in recent years, practitioners have come to realize that the two methodologies are, in fact, dependent on each other for greater success. For example, it is impossible to run a process with minimum waste or at a dependable capacity if individual process steps are highly variable. On the other hand, one can carefully study the complex processes, looking for root causes using elegant statistical techniques, and never make improvements in cycle-time or productivity that can be obtained from value-stream analysis.

To the extent Lean and Six Sigma approaches have their own strengths and weaknesses, the specific action plan to be followed in effectively implementing Lean Six Sigma (for example, Lean first followed by Six Sigma later or vice versa) is dependent on the nature of the situation at hand. For example, the problems related to accuracy and/or completeness are usually addressed best by the tools of Six Sigma; consequently, those tools should be introduced first. However, if the customer needs quick results, and if the problem is related to timeliness or productivity, Lean should be implemented first with an understanding that deep and complex problems will be solved only by the subsequent use of the Six Sigma tools.

In summary, Lean and Six Sigma are rich bodies of knowledge and are mature methodologies for solving a broad variety of process-related problems. Each methodology has its own approach to process improvement and its own tool set. Although Lean and Six Sigma methodologies can be mastered independently, they can and should be implemented together to realize the full benefits of process improvements by any organization.

Examples of Lean Six Sigma Implementations in the Military

The combination of Lean Thinking and Six Sigma has proven to be a very effective tool in the private sector. The success realized by top companies such as Toyota and GE has inspired the use of Lean Six Sigma in the US Department of Defense (DoD). Although the DoD has implemented a number of process-improvements methodologies with varying degrees of success in the past decade, it has begun to explore the potential of implementing Lean Six Sigma throughout the entire DoD only recently. The early results are very promising. As the lean Six Sigma mindset continues to grow among the DoD community and both the Lean and Six Sigma practices become more commonplace, the equipment and personnel available to the DoD will provide considerably more capability per taxpayer dollar than ever before. We discuss below some examples of Lean Six Sigma implementations in the US Army, Navy and the Air Force.

Army Implementations

Faced with the expectations of a shrinking defense budget, the Secretary of the Army Francis Harvey signed an order in March of 2005 that would implement Lean Six Sigma across the entire service. Currently, several organizations within the Army are implementing Lean Six Sigma and are enjoying remarkable results.

The Red River Army Depot Repair Facility is one such organization (Donnelly, 2006). In implementing Lean Six Sigma, the Red River Depot has made many changes to its HMMWV repair line, such as: forming an assembly-line process, using time-managed intervals to control the flow of work, organizing employees based on experience and proficiency, cleaning up and improving the overall work environment, stocking more and better quality parts to reduce stock-outs, and training employees to ensure there is no break in continuity on the assembly line. Improvement efforts have resulted in the ability to turn out 32 mission-ready HMMWV's a day, compared with three a week in 2004. The Lean process has also lowered the cost of repair for one vehicle from $89,000 to $48,000. Some of the biggest improvement ideas have come from the front-line employees themselves.

Other Army facilities boast similar progress as the result of Lean Six Sigma methodologies. Pine Bluff Arsenal in Arkansas reduced its repair cycle-time by about 90% and increased its production rate by about 50% on M-40 protective gas masks. Letterkenny Army

Depot in Pennsylvania has saved $11.9 million in the cost of building the Patriot air-defense missile system. In the Corpus Christi Army Depot, the overhaul time for one T700 helicopter engine was reduced by 64%. These depots improved the consistency of their repair operations by increasing the mean time between the engine overhauls from 309 hours to over 900 hours and improved the return to field accuracy to above 90% (Moorman, 2005).

Despite these early successes, the long-term, future and the resulting benefits of Lean Six Sigma are far from certain. Ultimately, the key ingredient for the successful implementation of Lean Six Sigma is not simply an order from the top, but the ability of commanders to change the organization's culture and convince the soldiers and employees that Lean Six Sigma does work and that it is worth the effort. The Red River Depot has taken a small, yet interesting, step to change the culture of the organization by posting a black cutout figure of a soldier with a helmet and rifle with a sign affixed to it that reads, "We build it as if our life depends on it. Theirs do!" This is to serve as a reminder that their job is about more than a paycheck, and the better they can do their job, the more lives they can save.

Navy Implementations

The *AIRSpeed* program is perhaps the best known implementation of Lean Six Sigma in the US Navy. As stated by the Secretary of the Navy Donald Winter in a memorandum in May 2006, "Lean Six Sigma (LSS) is a proven business process that several elements of the Navy and Marine Corps have initiated including training over 500 Black Belts and 1500 Green Belts who have facilitated 2800 events and projects. These activities have averaged a 4:1 return on investment." The following examples demonstrate some success stories in the implementation of *AIRSpeed*.

a. In October 2005, Naval Air Warfare Center (NAWC) accounting practices yielded an annual savings of $176.9K, with an additional anticipated saving of $146.3K in waste elimination.

b. Since April 2004, Aviation Intermediate Maintenance Division (AIMD) Whidbey Island reduced J-52 aircraft engine repair time from 468 hours to 233 hours and reported significant inventory and operating cost savings. Since February 2006, AIMD Patuxent River has seen increased savings due to a 10% inventory reduction and a reallocation of 166 hours of full-time employees.

c. In June 2006, Naval Aviation Systems Command's (NAVAIR) PMA offices began replicating successes of other PMA offices, including one office that saw an estimated $163K/year savings due to reducing processing time from the 240-days average to a predicted average of 15 days.

The successes are due, in large part, to the training received by the employees that emphasizes the use of DMAIC (Define, Measure, Analysis, Improve and Control) methodology for process improvement. *AIRSpeed* attempts to create an enterprise-wide, continuous process-improvement environment through the incorporation of commercial business practices. The goal of *AIRSpeed* is to operationalize cost-wise readiness across the Naval Aviation Enterprise.

There are five anticipated long-term benefits of *AIRSpeed*:

1. Reduce total cost of Naval Aviation by reducing inventory, manpower and operating expenses.

2. Support the Fleet Response Plan by providing aircraft Ready for Tasking (RFT).

3. Integrate the Maintenance and Supply Support System to provide seamless support to the Fleet.

4. Improve logistics and maintenance response by reducing cycle-time and the logistics footprint.

5. Place ownership and accountability at the appropriate levels.

Air Force Implementations

Over the next several years, the Air Force (AF) is expected lose approximately 40,000 personnel. This loss of manpower means airmen must work smarter and leaner. Senior AF leadership has decided to utilize the Lean Six Sigma strategy to accomplish this. Accordingly, the USAF has created a new program office, Air Force Smart Operations 21 (AFSO21), at the Pentagon with Brig. Gen. S. Taco Gilbert as the Director of the AFSO21 Office (Lopez, 2006).

The AF already has several examples of AFSO21 at work. AF Materiel Command has applied AFSO21 and returned 100 aircraft to duty, as well as reduced C-5 maintenance time by 50%. USAF Europe (USAFE) applied AFSO21 practices—they reduced the number of telephone operators by approximately 16% and saved the command $2.4 million (Lopez, 2006). The AF has also begun implementation of Lean Six Sigma concepts to their contracting activities. The goal is to reduce the cycle-time required to award a contract in support of new operational requirements. The Global Hawk team followed the Lean Thinking concepts to break down the contracting process into a value stream. They identified steps that do not add value and eliminated them. By eliminating those unnecessary steps, the process times in three steps of the contracting process were cut by 37%, 40% and 73%!

Managerial Implications

The experiences in implementing Lean Six Sigma in the military have uncovered several valuable lessons and managerial guidelines. They are briefly presented below.

Active support of senior leaders is a necessity.

- Articulate clearly the need for change.
- Commit to the change—make it last through leadership turnover.
- Change and accountability should be driven from the top.
- Actions speak louder than words—participate in the effort.

Initial successes are critically important.

- Carefully choose initial projects.
- Assign high-potential employees to those projects.
- Provide financial and personnel resources to ensure success.
- Initial successes turn the skeptics into believers.

Emphasize continuing education and training.

- Deploy 1% of workforce as full-time Black Belt plus Green Belts, Champions, etc.

- Black Belts should be selected from "future leaders of the organization."
- Create Master Black Belts to take over training at all levels.
- Senior organization leaders must be trained and engaged in project selection.
- Include Productivity Improvement Training in Leadership Development Programs.

Monitor the Lean Six Sigma projects.

- Assign concrete goals to project leaders and hold them accountable for project results.
- Provide stable funding to ensure long-term success.
- Demand validated return on investment; Keep score in public.
- Promote a philosophy that it is OK to save a dollar and give it up—it's not your money.
- Middle management is likely to provide the most resistance—actively manage their participation (increase the ratio between those that get it and those that don't).

The LSS methodology was developed in the private sector. To the extent the competitive environment, the organizational culture, and the nature of operational challenges are different in private-sector firms than in the Department of Defense, it is essential that the LSS methodology be suitably modified in its implementation in the military. We discuss below a set of issues that must be addressed in implementing LSS in the military.

Experience indicates that the success of Lean Six Sigma depends on employee empowerment and participative management. Since the military is traditionally organized and managed as a strict hierarchy, implementing LSS is a challenging task. Also, frequent rotation and movement of officers in their assignments is a common practice in the military. This creates a possibility that the procedures and culture created by one officer in implementing LSS can be disrupted when s/he is replaced by another officer.

In the military, the employees may enthusiastically embrace LSS implementation initially, but it is difficult to maintain that enthusiasm towards LSS in the long-run without proper incentive systems. Private-sector organizations can give financial incentives to employees to reward their contributions to process-improvement efforts. However, it is almost impossible to give such monetary incentives in the military due to the governmental rules and regulations. Hence, an alternate non-monetary incentive system, for example, for career enhancement or for better promotion opportunities, must be investigated.

Another area to be carefully studied regarding implementing LSS in the military is to understand the fundamental nature of military operations. Lean Six Sigma methodologies were originally designed for manufacturing assembly systems in which the demands are known or predetermined. As we move closer to a *foxhole* from a *factory*, the overall magnitude of uncertainty in demand, supply, and environment increases significantly. Military planners must fully keep in mind that the demand and supply are uncertain in many military applications; hence, LSS must be selectively implemented in different parts of the military in different ways. For example, supply officers may be *encouraged, but not required,* to apply Lean and just-in-time concepts to reduce inventory in military operational environments; such should not be required due to the inherent nature of uncertain demand and the potentially heavy penalty of stockouts that would cause readiness degradation and potential losses of human lives.

Finally, we wish to point out that while the issues identified above are important and must be carefully analyzed by military planners, approaches for dealing with them can be developed. Moreover,

the benefits of reduced lifecycle costs and improved readiness that can be realized from implementing Lean Six Sigma are simply too great. Hence, we believe that implementing Lean Six Sigma in the military is a strategically important logistics initiative and recommend that it be undertaken under full steam.

Acknowledgments

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Beyond AIR*Speed*: How Organizational Modeling and Simulation Further Reduced Engine Maintenance Time

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Abstract

Aircraft Intermediate Maintenance Division at Naval Air Station Lemoore achieved time and cost reductions using the NAVAIR Enterprise AIR*Speed* program of Lean, Six Sigma and Theory of Constraints, but could changes in organization structure or management practices provide further improvements?

Organizational simulation software was employed to test interventions that could reduce throughput time for the F414 aircraft engine. A baseline model was developed, and interventions were modeled and simulated. The simulated results indicated that paralleling some tasks could significantly decrease maintenance duration while maintaining quality. The intervention was implemented—saving 26 days per engine. Organizational modeling and simulation can identify and pre-test time and cost savings over and above techniques such as Lean and Six Sigma.

Key words: Organizational modeling, organizational simulation, Logistics, Lean, Six Sigma

Introduction

The Aircraft Intermediate Maintenance Division (AIMD) at Naval Air Station (NAS) Lemoore, CA, has worked aggressively to reduce engine maintenance time using the tools of the NAVAIR Enterprise AIR*Speed* (AIR*Speed*) program. AIR*Speed* is a system created by the Naval Aviation Readiness Integrated Improvement Program's (NAVRIIP) to enable cost-wise readiness across the naval aviation enterprise (Naval Air Forces Public Affairs Office, 2006). AIMD Lemoore has achieved time and cost reductions at the maintenance activity level using AIR*Speed's* prescribed tools of Theory of Constraints, Lean, and Six Sigma, but could further improvements be made by changing the organization structure or management practices?

In an effort to answer this research question, AIMD Lemoore teamed with the Naval Postgraduate School's (NPS) Graduate School of Business and Public Policy to explore organizational modeling as a method for identifying potential modifications to the organization which may improve AIMD performance. Specifically, AIMD leadership focused on improving F414 aircraft engine maintenance by decreasing engine throughput duration.

The objective of this effort was to provide the NAS Lemoore AIMD 400 Division, the Division responsible for F414 maintenance, with recommendations on how their organization may be restructured in order to decrease F414 maintenance cycle-time. To meet this objective, NPS developed an organizational model of the 400 Division which described their current F414 maintenance process. This model was then modified to characterize the impact of organizational changes on maintenance cycle-time.

This paper is organized into four sections. The first, a literature search, provides a basis for understanding organizational modeling in general as well as techniques specific to the

POWer software developed by Dr. Raymond E. Levitt's Virtual Design Team (VDT) research group at Stanford University and employed in this project. The second section discusses the methodology for conducting this study. The third section presents the results of the modeling effort. Finally, section four presents project conclusions, recommendations for restructuring the 400 Division, and recommendations for future research.

Computational Organizational Modeling

In the 21st Century, computational organizational modeling, a new predictive modeling technique, has come of age. It is a tool which has the potential to assess how changes to an organization may or may not benefit the organization's performance (Levitt, 2004). Computational organizational modeling as a tool for improving quality is different from many other quality-improvement techniques such as Lean, TOC, or Six Sigma in that it does not focus on the production process, but instead on the organizational structure that manages that production process, and the information flow through that organization necessary to execute the production process. It is based upon the understanding that by improving the quality of the organization and the flow of information through that organization, the quality of the organization's output can be improved.

The technique of organizational modeling is analogous to modeling employed in the natural sciences, such as finite element modeling (FEM) or computational fluid dynamics (CFD) modeling. FEM and CFD modeling both break down the larger structure being modeled into smaller elements, with each element having its own characteristics: e.g., modulus of elasticity, density, viscosity. With an understanding of how these elements interact, the overall effect of a force or moment on the larger structure can be assessed. Similarly, organizational modeling is accomplished by breaking down an organization into smaller elements such as tasks, people, and communication methods—each with their own characteristics, e.g., time required to accomplish a task, worker experience, communication clarity—and predicting how changes to an organization may affect each element and, subsequently, how those elements in turn affect the overall organizational performance (Levitt, 2004).

This detailed level of organizational characterization theoretically allows managers to design their organization in the same way that engineers design bridges. Organizational modeling allows managers to perform "what-if" analyses, evaluating, in a virtual environment, the effects of organizational constructs in order to identify the structure resulting in the best output. Gaining similar insight without the aid of a modeling tool would be prohibitive. Organizations could not withstand the dynamics of change after change simply to determine what works best and what does not.

The organizational model employed in this project is POWer, version 1.1.6. It was developed by Dr. Raymond Levitt as part of a suite of Virtual Design Team (VDT) simulations at Stanford University.

Virtual Design Team—POWer

POWer evolved from the Virtual Design Team simulations, which are based on macro-contingency theory and describe work in terms of information flow (Thomsen, Kunz, Levitt & Nass, 1998). POWer is based on the premise that no matter what business an organization is in, be it production of widgets, design of skyscrapers, or providing hotel rooms, one thing they all have in common is they must process information effectively to do their job well (Kunz, 1998).

Theoretical Basis for POWer

The concept that organizations can be modeled in terms of information flow is based on J.R. Galbraith's theory of information processing. According to Galbraith, information transfer and processing is dynamic. Due to the complexity of information and, many times, the sheer amount of it, there are often instances in which an individual is unable to process all of the information he is given because he does not have the skill or experience to make decisions quickly enough. As a result, an *exception* (as Galbraith defines it) is created. Exceptions are common in today's fast-paced world in which we are inundated with requests from e-mail, cell phones, black-berries, etc. In Galbraith's view, organizations are modeled primarily as hierarchies; it's through these hierarchies that exceptions are passed up the "chain of command" to be handled by more experienced individuals. Along with the hierarchical structure by which exceptions are passed, Galbraith notes there are also exchanges of information between individuals at equal levels in an organization. These information exchanges can also be used to handle exceptions, and are often more effective than those moving up the chain of command since they tend less to overload upper-level managers and create additional exceptions (Thomsen, Kunz, Levitt & Nass, 1998).

Methodology

The researchers visited the NAS Lemoore in order to conduct multiple interviews with 400 Division personnel. Information was collected to properly structure the 400 Division model in POWer and accurately characterize the properties of each software element. Through these exchanges, a baseline model was created that accurately characterized the operation of the 400 Division F414 maintenance process.

Modifications, also termed "interventions," were identified which have potential for decreasing F414 maintenance throughput. Each intervention was separately created by modifying the baseline model. Comparisons between these modified and baseline models were made to determine the utility of each intervention. Finally, a combined intervention model incorporating all individual interventions deemed beneficial was developed and compared to the baseline model.

Figure 1 presents the baseline model of the 400 Division. The slanted boxes at the top of the figure represent meetings. The human-shaped symbols represent positions within the division. The boxes in the center of the figure represent the primary F414 maintenance tasks, while the boxes in a vertical line on the left represent the off-core tasks. The remaining polygons represent milestones in the maintenance process.
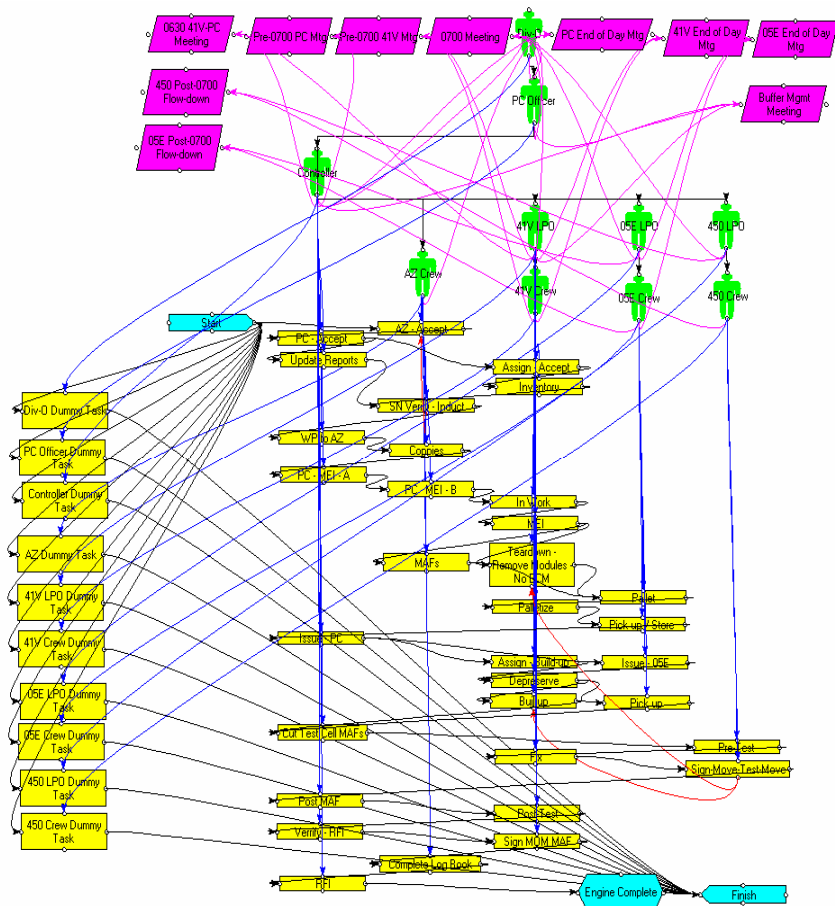
Figure 1. Organizational Model

The positions modeled were those that directly impacted F414 maintenance. Positions were modeled in terms of the number of personnel assigned, amount of time available to work F414 tasks, qualifications, skill levels, and experience. Since this engine was one of the six engines the division maintained, the time as allocated was 1/6 of the actual time available. In addition, off-core tasks described below were added to a positions' workload to occupy their time when not conducting F414 maintenance. Figure 2 presents the organizational structure.
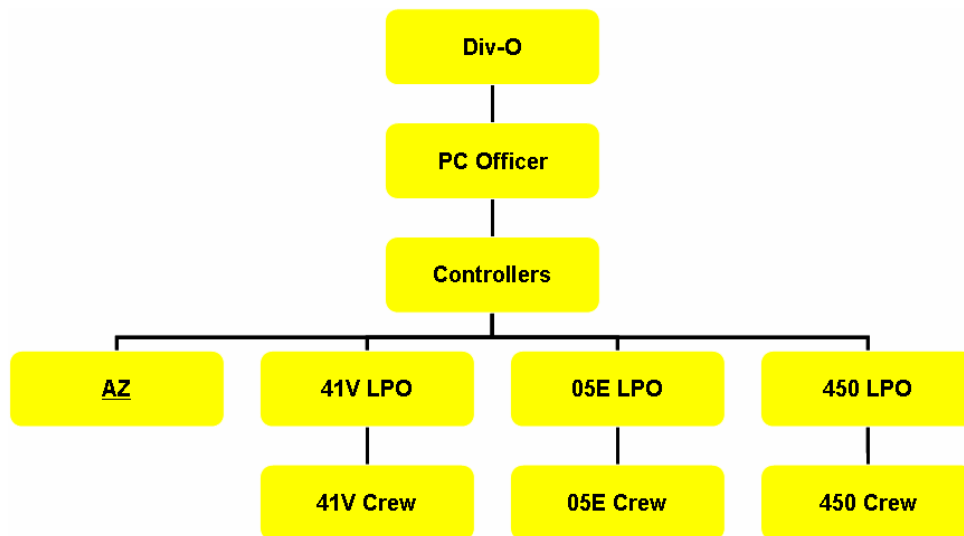
Figure 2. NAS Lemoore AIMD 400 Division Information Hierarchy

The terminology used in Figure 2 and throughout this report to reference individuals and groups is consistent with terminology used in the Navy's AIMD. For clarity, these terms are defined as follows:

Div-0: Division Officer

PC Officer: Production Control Officer

AZ: administrative personnel

41V: personnel who directly conduct F414 maintenance

05E: supply personnel dedicated to the division

450: personnel responsible for conducting final tests of the F414

LPO: Leading Petty Officer, responsible for the workcenter

Tasks were modeled in terms of duration, required skills, priority, and complexity. Modeled tasks are presented in Figure 3. The following is a general description of the F414 maintenance process.

After the engine is received, AZ personnel begin by comparing information in the engine logbook to information in two central databases, AEMS and SAME, which track engine parts and engine movement. Prior to maintenance action commencing on the engine, AZ personnel must resolve any discrepancies. Once completed, 41V personnel conduct a major engine inspection (MEI) followed by an engine teardown to determine which engine modules need replacing. Replacement modules are pulled from supply by 05E personnel. The engine is reassembled or "built-up" by 41V personnel, and then sent to the test cell, where 450 personnel run it through pre-defined profiles assessing operability. The engine is returned to the maintenance hanger where 41V personnel conduct a post-test inspection. At this point, AZ personnel complete paperwork; Controller personnel sign off the engine as ready for issue (RFI)

to an operational squadron. Throughout this process, Controllers are directing the maintenance activities.
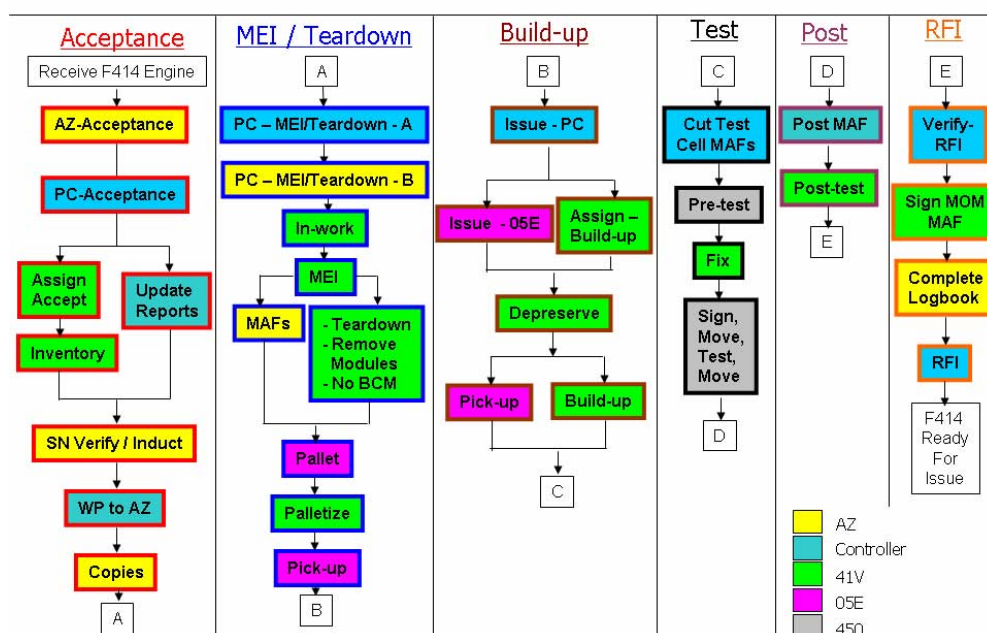
Figure 3. Work Breakdown Structure of the F414 Engine Maintenance Process

To ensure positions were continually occupied throughout the F414 maintenance process, as they would be in reality, off-core tasks were added to the model to simulate maintenance work being accomplished by personnel, other than maintenance of the single engine being modeled.

Meetings were modeled in terms of duration, who attended, priority and interval time between meetings. Meetings were a key method of reliably transferring information between personnel. In general, the division had a set of morning meetings and a set of afternoon meetings.

Rework was modeled as a percentage of work accomplished. Most F414 rework occurred at the test-cell phase of maintenance. The percentage of rework was based on 400 Division estimates.

Additional organizational characteristics modeled included the overall experience level of the division, the degree of centralized control, the degree of formality in transferring information (i.e., meetings versus hallway conversation), and the matrix strength or connectedness of personnel.

Model Validation Procedure

Once the model was constructed, the maintenance duration predicted by the model was compared to the actual time it should take to conduct engine maintenance. The actual time was calculated by summing the duration of all tasks occurring in series and the longest duration task of any grouping of tasks occurring in parallel. The smaller the difference was between these

values, the higher the confidence in the model, and, hence, the predicted impacts of interventions.

Model Interventions

Once the model was determined to accurately depict the current organization, modifications or interventions were made to evaluate alternate organizational constructs which might reduce throughput duration. The following interventions to the baseline model were evaluated.

1. Parallel AZ Acceptance task with other maintenance tasks
2. Combine AZ and Controller positions
3. Combine 41V and 450 positions
4. Decrease organization's centralization
5. Add additional personnel to each position
6. Alter current meetings' duration and frequency
7. Combine meetings
8. Conduct a combined intervention

The current F414 maintenance process presented in Figure 3 shows a serial process initiated by the AZ Acceptance tasks.

Intervention 1: Considered the impact of conducting the AZ Acceptance tasks in parallel with all other maintenance tasks.

Intervention 2: Personnel assigned to the AZ and Controller positions are combined into a single position. This position is assigned the combination of tasks originally assigned to the separate positions. This intervention was evaluated in two sub-interventions, first without retraining individuals and then with retraining.

Intervention 3: The same as Intervention 2, with the work positions combined.

Intervention 4: One of the impacts of AIR*Speed* is to decrease the centralized control of an organization by pushing authority for decision-making to the lowest possible level. This fourth intervention assessed the impact of the division's further decreasing centralization.

Intervention 5: Assessed the impact of adding additional personnel to existing positions. Personnel were added separately to AZ, Controller, 41V Crew, 05E Crew, and 450 Crew positions while holding personnel at all other position constant.

Intervention 6: Considering maintenance tasks are well defined and the personnel are highly skilled, it's conceivable that that altering meeting duration and/or frequency may decrease F414 throughput duration. This intervention evaluated altering the duration and frequency of the 0700 morning meeting, the Division's primary coordination meeting.

Intervention 7: For the same rationale as intervention #6, this intervention evaluated the impact of combining all of the morning meetings while leaving the afternoon meetings separate.

It then evaluated the impact of separately combining all morning meetings and all afternoon meetings.

Intervention 8: Based on the results of the single interventions, a combined intervention was developed which included those interventions presented above that decreased the F414 maintenance throughput time.

Evaluating Interventions

Interventions were evaluated by comparing four metrics predicted by the baseline model to those predicted by the models with interventions. The first metric was project duration, the duration required to accomplish maintenance of a single F414. Duration was considered the most important metric. The second metric was position backlog, a measure of the number of days of work a position has yet to accomplish. It is analogous to the size of a person's in-box. A position with a high backlog poses a risk of increasing project duration and decreasing output quality. Position backlog is presented as a line graph of number of backlog days versus time. The third metric was cost. Although absolute cost was not a concern for this study, changes in costs resulting from interventions were. Of particular interest were interventions resulting in increases in costs associated with the major tasks of engine teardown, buildup, and testing. Cost was calculated by the simulation and output in both text and graphic. The fourth metric was functional risk, the risk that an engine has defects due to rework and the inability of personnel to handle problems. Qualitative comparisons of functional risk were made using output charts of the functional risk.

For any given intervention, the impact on each of the four metrics was categorized as positive, negative, or no impact and given a rating respectively. For example, a decrease in project duration resulting from an intervention would be considered positive, while an increase in cost or risk would be considered negative

Results

The Results section begins with a presentation of the baseline model validation results. The baseline model is followed by a summary of the results of the seven individual interventions and the combined intervention. Finally, there is a discussion of which interventions were implemented and their impact on F414 maintenance duration.

Baseline Model Evaluation

The actual time required to conduct F414 maintenance was calculated to be 21.77 days—compared to the baseline model prediction of 21.09 days. Since these two durations were within 3% of each other, there was high confidence that the baseline model was accurate.

Interventions—Summary of Results

Table 1 presents a summary of the intervention results. The first intervention, paralleling the AZ Acceptance Task, has the greatest benefit on decreasing F414 throughput duration. Other interventions that were beneficial included decreasing centralization, and separately combining the morning and afternoon meetings. The combined intervention, incorporating all of these beneficial interventions, resulted in a 35% decrease in F414 throughput duration with a slight decreasing in the backlog of most of the personnel. A detailed discussion of the analysis

and results associated with Intervention 1 is presented in the following sub-section. All other interventions (including the combined intervention) were analyzed in the same manner.

Intervention	Project Duration	Backlog	Cost	Risk
1. Parallel AZ Acceptance	58.56 hour decrease	Decrease most positions	No significant impact	Increase in AZ Acceptance task risk
2a. Combine Controller & AZ positions without training	110 hour increase	Decrease controller & AZ, Increase for Div-O & PC	AZ Acceptance task work & rework cost increase by 205.6 & 11.72 respectively	Increase in AZ Acceptance task risk
2b. Combine Controller & AZ positions with training	56.7 hour increase	Decrease in Controller & AZ backlog. Increase for Div-O & PC	AZ Acceptance task work & rework cost increase by 140.1 & 18 respectively	Increase in AZ Acceptance task risk
3a. Combine 41V and 450 positions without training	132.6 hour increase	Slight decrease in 41V and 450 backlog	Increase costs: Buildup & rework—267.16 and 7.2, Test work, rework, and wait costs—1085, 61.5, 290.2	3/4 top risk areas assigned to combined 41V-450 vs 2/4 currently
3b. Combine 41V and 450 positions without training	67.6 hour increase	Slight decrease in 41V and 450 backlog	Increase costs: Buildup work – 267.15 & test work, rework, and wait costs – 303.4, 5.63, 93.41	3/4 top risk areas assigned to combined 41V-450 vs 2/4 currently
4. Decrease Centralization	4.4 hour decrease	No significant impact	Slight increase in Buildup task rework costs of 9.86	No significant impact
5a. Add AZ personnel	1.87 min saved / person	No data collected	No data collected	No significant impact
5b. Add Controller personnel	6.82 min lost / person	No data collected	No data collected	No significant impact
5c. Add 41V Crew personnel	0.91 min lost / person	No data collected	No data collected	No significant impact
5d. Add 05E Crew personnel	10.51 min saved / person	No data collected	No data collected	No significant impact
5e. Add 450 Crew personnel	4.42 min saved / person	No data collected	No data collected	No significant impact
6a. Vary 0700 meeting duration & frequency	6.56 hours saved due to less frequent meeting	No data collected	No data collected	No significant impact
6b. Vary 0630 meeting frequency	1.6 hours saved due to less frequent meetings	No data collected	No data collected	Slight increase in risk when increasing time between meetings
7a. Combine only morning meetings	No significant impact	No data collected	No data collected	No significant impact

| 7b. Separately combine morning and end of day meetings	7.28 hours saved by decreasing meeting frequency to every other day	No data collected	No data collected	No significant impact
8. Combined Interventions	58.96 hours saved	Decreases most positions. Increases 450 LPO	Buildup rework decreases by 26.3; Teardown rework increases by 10.49	No significant impact

Table 1. Simulation Results for Interventions by Duration, Backlog, Cost and Risk

Intervention 1, paralleling the acceptance task with maintenance, decreased project duration by 7 days from the base model prediction of 21.09 days to 13.77 days. The impact of this intervention on individual task durations and the overall duration are depicted in Figure 4. The dark bars represent the duration of the individual maintenance tasks—with the exception of the second through eleventh bars, which represent off-core tasks. The decrease in maintenance duration is the result of starting on-engine maintenance tasks at the same time as the AZ Acceptance task. In the current process (Figure 4 left chart), the 14-day AZ Acceptance task must be accomplished before any other tasks. This intervention (depicted in the right chart in Figure 4) allows the engine-maintenance-related tasks to begin at the same time as the AZ Acceptance task.
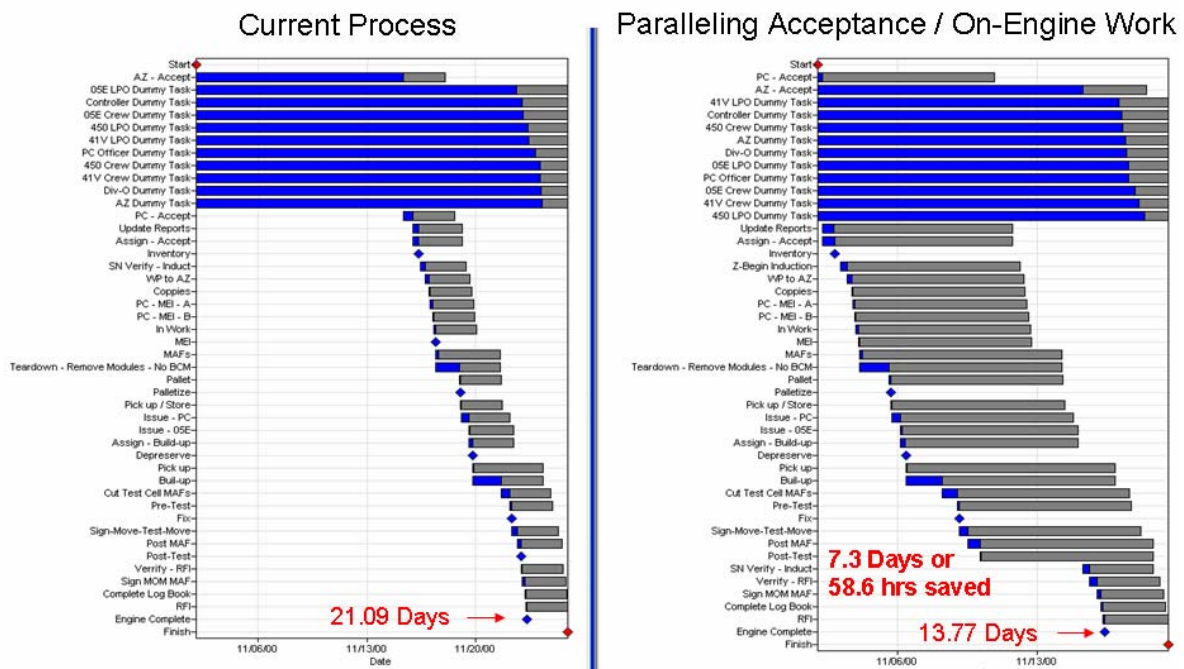

Figure 4. Comparison of Project Duration for Intervention 1

Figure 5 presents a comparison of the position backlog of the baseline model and the model employing the intervention. The comparison shows a slight decrease in position backlog resulting from Intervention 1.
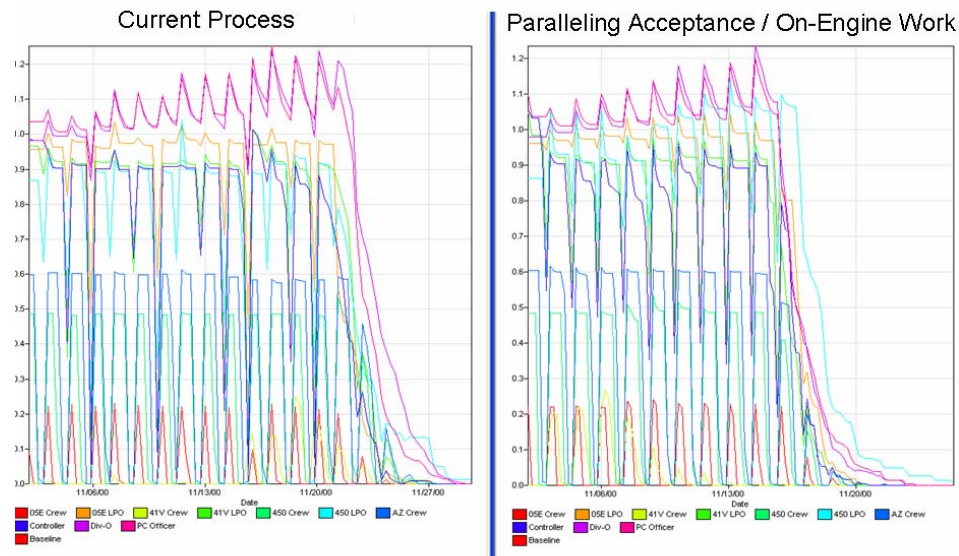
Figure 5. Comparison of Position Backlog for Intervention 1

Figure 6 presents a comparison between baseline model costs associated with the model employing the intervention. Figure 6 indicates no significant impact on cost.
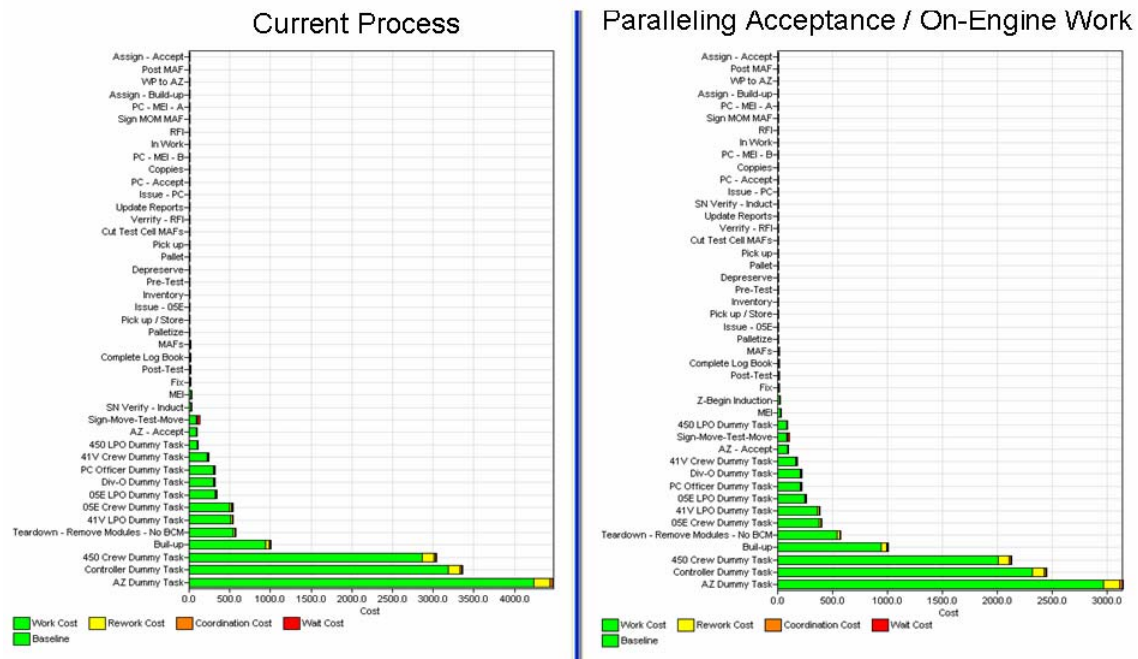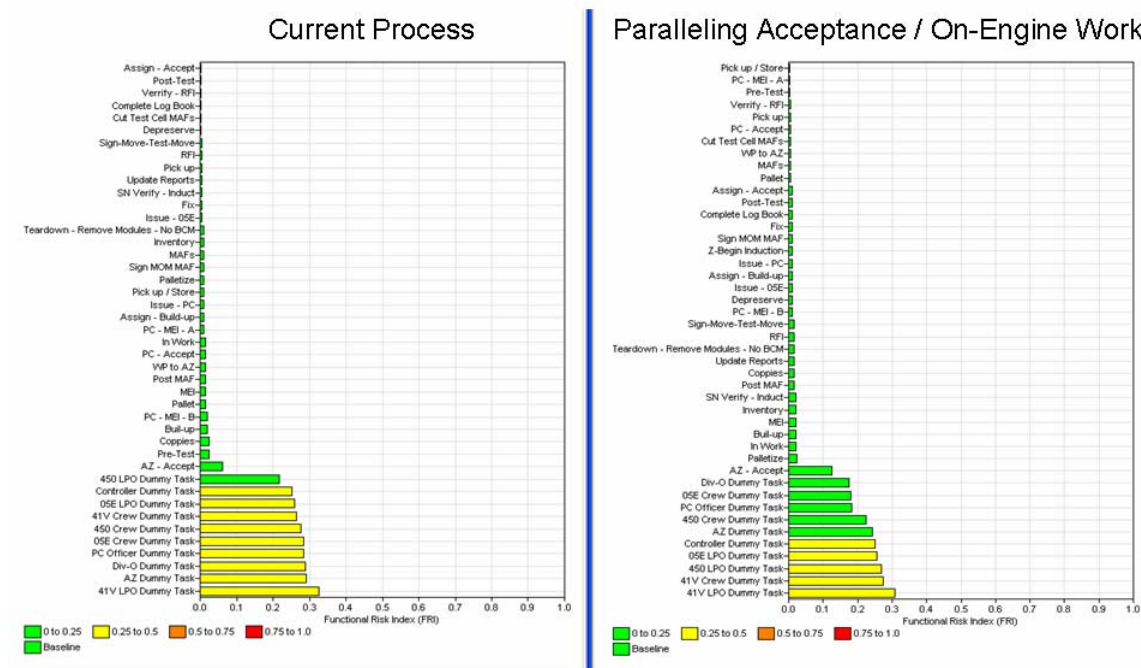

Figure 6. Comparison of Cost for Intervention 1

Figure 7 presents a comparison of the baseline model functional risk with the functional risk for the model implementing Intervention 1. This comparison indicates a slight risk increase for the AZ Acceptance task. This is not unexpected since this task is now being accomplished

in conjunction with other tasks; hence, the time originally devoted by Controller personnel to assist AZ personnel in handling problems must now be devoted not only to AZ personnel, but to other personnel concurrently working engine-maintenance tasks.

Figure 7. Comparison of Functional Risk for Intervention 1

The overall rating for Intervention 1 is presented in Table 1. This intervention was considered beneficial because it resulted in a significant decrease in project duration, a slight decrease in position backlog, no significant impact on cost, and only a slight increase in functional risk for a single task.

Intervention #8—Combined Intervention

The combined intervention included the following interventions, which were chosen for being the most beneficial:

Intervention #1—Paralleling the acceptance task

Intervention #4—Decreasing centralization from high to low

Intervention #6—Decreasing 0700 meeting frequency to every 2 days

Intervention #7—Separately combining morning & afternoon meetings

The impact of these combined interventions on project duration was a decrease from 21.09 days to 13.72 days. The backlog for most positions decreased with an increase in only one position, the 450 LPO. There was a slight increase in Teardown task rework cost from $26.44 to $36.93, and a slight decrease in the Buildup task rework cost from $48.43 to $22.13.

Overall, the changes in cost were not considered significant. Finally, there was no significant impact on functional risk.

Assessment of interventions

The results of this study lead to the conclusion that four of the seven interventions to the division considered in this study would be beneficial to reducing the throughput duration: paralleling the AZ Acceptance task, decreasing centralization, decreasing 0700 meeting frequency, and separately combining morning and afternoon meetings.

The greatest benefit to reducing the F414 throughput duration comes from paralleling the AZ Acceptance task. Although this intervention increases functional risk, this increase is minor relative to the decrease in throughput time by 7.21 days. There is also a consequent decrease in position backlog.

Decreasing centralization, a benefit realized through the implementation of AIR*Speed,* also has a positive impact on decreasing F414 throughput. This intervention resulted in a 4.4-hour decrease in duration.

By decreasing the 0700 meeting frequency from every day to every other day, F414 throughput duration decreases by 6.56 hours. This benefit is the result of a highly skilled workforce executing well-defined tasks, allowing personnel to spend more time working on engine maintenance and less time exchanging information in meetings.

By separately combining morning and afternoon meetings such that there is one morning meeting and one afternoon meeting that all personnel attend, F414 throughput duration decreases by 7.28 days. At the same time, there is also no increase in functional risk.

Unfortunately, benefits associated with combining these four interventions are not additive. This makes sense based on their interrelated nature. When combining interventions, the benefit to reducing F414 throughput duration is nonetheless significant in that there is a reduction of over 35% from the baseline case representing the current organization. In conjunction with this benefit, there is a decrease in backlog for all positions excluding one, the 450 LPO, and there is no adverse impact to cost or functional risk.

Two other interventions considered, combining the AZ and Controller positions and combining the 41V and 450 positions, resulted in increases in F414 throughput duration as well as increases in cost and risk, with the only predicted benefit being a decrease in position backlog for the combined positions. Clearly, these interventions are not beneficial.

Finally, the intervention associated with adding additional personnel did not affect F414 throughput duration, and had no impact on risk. Obviously, there would be no benefit to implementing this intervention.

Recommended Interventions

- NPS recommended the 400 Division implement the following interventions

- Decrease 0700 morning meeting frequency to every other day.

- Separately combine morning and end-of-day meetings

- Parallel the AZ Acceptance task

The first and each subsequent intervention recommendation should be implemented, followed by a period of evaluation. The priority order of these interventions is based on first implementing those interventions that can most easily be reversed. For example, conducting the 0700 meeting every other day is a relatively easy organizational change which should result in a decrease in F414 throughput duration. At the same time, it is an organization change that can be reversed if deemed necessary.

Impact of implementing interventions

The NAS Lemoore AIMD and 400 Division leadership had significant confidence in the results of this study, and chose to fully implement the recommendation to parallel the AZ acceptance task while partially implementing the recommendation to separately combine the morning and afternoon meetings. The impacts of these decisions were quickly realized and deemed successful. The following discussion presents three instances in which paralleling the AZ acceptance task significantly reduced F414 maintenance throughput time. Table 2 at the end of this section presents a summary of these results. Following this is a discussion of how partially combining 400 Division morning meetings improved organizational performance.

On 20 October, the 400 Division received F414 serial number 868472 from VFA106, NAS Oceana. On that same day, the engine-acceptance process commenced. During the acceptance process, SAME database problems were identified. Recall that the SAME database, described earlier in this paper, is an historical record of maintenance actions accomplished on each engine. Often, an engine is received by the 400 Division for which there are discrepancies between data contained in the SAME database and the engine log book. These SAME discrepancies were resolved on 7 November. Prior to implementing the intervention of paralleling the AZ acceptance process, teardown would not have started until after the SAME database problems were resolved on 7 November. By implementing this intervention, however, engine maintenance began on 23 October when personnel were available—saving 16 days, the difference between 23 October versus 7 November. (See Table 2.)

In the second observation, on 25 October, the 400 Division received F414 serial number 868083 from VFA-2. SAME database problems were identified on 26 October which were resolved on 13 November. By choosing to implement the intervention of paralleling the AZ acceptance process, maintenance on this engine commenced on 29 October versus waiting until 13 November, thus saving 16 days.

Finally, on 5 September, the 400 Division received F414 engine serial number 868265 from the USS Lincoln. On that same day, SAME database problems were identified which were eventually resolved on 16 October. A total of 46 days were saved in this case by paralleling the AZ acceptance process since maintenance on this engine started on 6 September. (See Table 2.)

Engine Serial Number	Engine Received	SAME Problem(s) Identified	SAME Problem(s) Resolved	Engine Maintenance Started	Days Saved
868472 VFA-106	20 Oct	20 Oct	7 Nov	23 Oct	16
868083 VFA-2	25 Oct	26 Oct 06	13 Nov	29 Oct	16
868265 USS Lincoln	5 Sep	5 Sep	16 Oct	6 Sep	46

Table 2. Summary of Intervention Results

Like the impacts presented in Table 2, the AIMD and 400 Division leadership's decision to combine certain aspects of their morning meetings also had a positive impact on decreasing the time required to conduct F414 maintenance. Specifically, LPO coordination efforts conducted at both the 0630 and 0700 meetings were combined. At the same time, the duration spent by each LPO in this combined meeting was decreased, allowing them to more quickly provide direction to their subordinates.

At the time of this article's writing, this intervention had just recently been implemented, and quantitative results of its impact were not yet available. Qualitatively, though, the Division Officer in charge of the 400 Division has identified a marked improvement in the amount of work being accomplished as a result of implementing this intervention. Prior to its implementation, upon his arrival to the office at 0630 each day, the Div-O would see a significant amount of coordination work being accomplished by LPO and PC personnel in preparation for the day's work. Following the combination of morning meetings, the Div-O arrives at work and now sees personnel working on the F414 engines. Information flow is being accomplished more smoothly, thus allowing coordination efforts to be accomplished more quickly; hence, more work is accomplished on a given day.

The AIMD and 400 Division leadership are pleased with the results of these interventions. Both quantitatively and qualitatively, their impacts have resulted in shorter F414 throughput time and improved organizational performance through better information flow.

Limitations and Future Research

This project only considered that portion of the AIMD 400 Division that accomplishes F414 maintenance. It considered only tasks associated with maintenance efforts starting from receipt of the engine to the point at which the engine is determined ready for issue (RFI). Although other maintenance work and collateral duties not directly associated with F414 maintenance were not directly modeled, generic, non-core tasks were modeled which required personnel to perform functions other than F414 maintenance. By doing so, limitations on 400 Division personnel's time to accomplish F414 maintenance were accurately characterized. The scope of this effort was further limited by modeling the maintenance of only a single engine, although total available time to accomplish tasks were correspondingly decreased to that available for a single engine.

Future research is needed to track AIMD performance post-implementation of selected interventions and to compare data to predicted performance. Other organizations within the NAS Lemoore AIMD (e.g., Airframe Division, Avionics Division, etc.) should also be separately

modeled to identify potential organizational changes which may improve their processes. Consideration should then be given to integrating these separate models to develop a coherent AIMD model which would aid in identifying modifications to the larger organization, thus benefiting information flow. The model developed for this study could also be modified to represent engine maintenance divisions in other AIMD units across the Navy.

Conclusions

This study in applying organizational modeling to the NAS Lemoore AIMD identified several potential modifications or interventions to the 400 Division which could reduce F414 engine-maintenance throughput time. These interventions went beyond the process-improvement techniques implemented by the division under the AIR*Speed* program by focusing primarily on improving how and when the flow of information through the organization occurs.

Results have shown a savings between 16 and 46 days of maintenance time on each engine: an average of 26 days per engine. The Leadership also chose to partially implement the intervention of separately combining morning and afternoon meetings. Personnel now receive direction on required daily maintenance actions more quickly, which has increased the amount of work accomplished each day.

Organizational modeling provided key insights into improving the NAS Lemoore AIMD F414 maintenance process and allowed management to consider the likely impacts of alternatives on time, cost and quality prior to making these changes. The significant improvement in reducing F414 maintenance throughput time that resulted from this study affords high confidence in achieving future improvements in other Navy maintenance organizations via the tools and techniques of organizational modeling.

Organizational modeling has great potential for improving on outstanding process-improvement results the Navy has already achieved under the AIR*Speed* program.

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